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ABSTRACT

A significant portion of the energy in the United States today is used for comfort cooling and heating. Fifteen or twenty years ago, when energy was inexpensive, there was little economic pressure for engineers to provide an energy efficient facility design. In recent years, energy efficiency has become a significant consideration in the design of a new facility. To aid in the design effort, many computer programs have been developed to predict energy use. The complexity of these programs has made them difficult to use and not readily accessible to the practicing engineer. The objective of this work is to develop a simple tool for characterizing facility energy consumption as a function of the space loads, the HVAC system and control method selected and appropriate equipment parameters. Theses, [illegible],

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This thesis describes the theory behind the equations used in the program and the logic used to develop the computer code. The program was tested by performing case studies, each consisting of several twenty-four hour simulations. A loads and weather data base from a single-story Phoenix, Arizona facility was used for the case studies. The results of these studies show that the program reacts well to system, control and economizer variations. Although future refinements and additions are

possible, the simplified tool developed in this work should prove beneficial to the HVAC engineer, especially for peak loading parametric studies.

A SIMPLIFIED CHARACTERIZATION OF HVAC SYSTEM

DESIGN ON BUILDING ENERGY USE

APPROVED:

Dedicated to my loving and understanding wife,

Laura Lynne Reardon

and to my son,

Kent Alexander Reardon.

A SIMPLIFIED CHARACTERIZATION OF HVAC SYSTEM DESIGN ON BUILDING ENERGY USE

by

MICHAEL KENT REARDON, B.S.

THESIS

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

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August 1987

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The University of Texas at Austin M.K.R.
May 15, 1987

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CHAPTER 1

BACKGROUND

1.1 INTRODUCTION

A significant portion of the energy in the United States today is used for comfort cooling and heating. Fifteen or twenty years ago, when energy was inexpensive, there was little economic pressure for engineers to provide an energy efficient facility design. In recent years, energy efficiency has become a significant consideration in the design of a new facility.

To accomplish this end, many computer programs have been developed to predict energy use. Too few of these are geared to microcomputers and thus, mainframe computers must be used. For small engineering consulting firms, the use of mainframe programs may either be cost or time prohibitive. Microcomputers are emerging as an essential tool in many aspects of the design process. Even the smallest consulting firm is now usually equipped with a microcomputer. Thus, emphasis on the development of energy design aid programs has switched from the mainframe to the microcomputer. A number of microcomputer based energy programs have been developed. However, they generally do not provide a mechanism for examining the effects of variation in HVAC system control strategies on energy use. Thus, the objective of this research has been to develop a simple tool for characterizing facility energy consumption as a function of the space loads, the HVAC system and control method selected and appropriate equipment parameters. In this development, zone and envelope loads were taken as given inputs for this analysis. Thus, the focus of this work has been the development of a simplified system simulation

program to be used to characterize HVAC system performance as a function of systems and control strategy selection. The main emphasis was to provide a product which was tailored for a microcomputer, easy enough for the designer who has little experience operating a microcomputer and which provided the greatest amount of flexibility for selecting system parameters in systems design. This would provide a means of choosing an HVAC system which would produce the most energy efficient facility design in the minimum amount of time. Aside from its use for future research and subsequent inclusion in an overall simplified characterization of facility energy use, this work was tailored to allow the designer to see the effects of system and control parameter variation on system load over a twenty-four hour period. Such results could be beneficial in the reduction of peak system demand, as well as, energy conservation.

This work's intent was not to provide a tool for accurately predicting energy consumption; but rather to enable the designer to compare possible HVAC system and control strategies for a particular facility and location relative to other systems and strategies available.

The HVAC systems considered specifically were the Terminal reheat system, Variable Air Volume (VAV) system with induction type reheaters and a cycling system with varying control and economizer options. The control strategies modeled were a fixed cooling coil set point method, a zone controlled method and an outside air control method. This last method requires a schedule, which matches a leaving coil air temperature with a specific outside air temperature, be input by the user of the program. The economizer options included the use of an outside air dry bulb temperature economizer, enthalpy controlled economizer or no economizer at all. Under the specific objectives of this work, fans were modeled only to the extent that their

performance affected the temperature of the supply and return air mixture. Constant speed, variable speed and cycling fans, as well as the use of inlet or discharge dampers for control, were included in the program. Since not all systems have the fan motor directly in the air stream and others do not even use a return fan, these were also made options to the user. Additionally, this tool allows the researcher to vary the amount of insulation installed on the duct work, the air velocities in the duct system, the fraction of lighting energy which is released into the return plenum, the ceiling panel transmission values, the maximum outside air temperature allowed for economizer operation, the amount of air leakage into the plenum and the maximum leaving coil air temperature.

1.2 LITERATURE REVIEW

Of the numerous mainframe energy prediction computer programs which have been developed, two seem to have emerged as the most frequently used by the engineering profession. These are the Building Loads Analysis and System Thermodynamics (BLAST) Program and DOE 2 series programs.

The BLAST Program was developed by the Construction Engineering Research Laboratory of the U.S. Army. Its strength lies in its treatment of some specific heat flows within facilities. It is not as widely accepted or utilized as the DOE 2 series programs because it is not able to simulate a wide variety of HVAC systems and controls strategies. Since the main thrust of this work was on the system rather than the space loads level, the BLAST program was not examined in detail.

On the other hand, the DOE 2 series programs, developed and maintained by at the Lawrence Berkeley Laboratory, are able to handle many different systems and controls strategies. The 2.1C version of this program was examined more carefully.[1,2] The

zone extraction rates (space loads) and weather data used in the case studies presented here were taken from DOE 2.1B output. The decision was based on the accessibility to the program and its ability to produce output in the form required for input to the program developed by this research.

One simplified method for determining facility energy consumption, using the Modified Bin Method, was developed by a team headed by David E. Knebel.[3] Knebel's team used averaging techniques in the determination of space and system loads. These techniques may lead to inaccuracies when faced with the loads for a massive facility but, as with this work, the team decided that the added accuracy was outweighed by the increased computational complexity. Their work resulted in a computer code which included five HVAC systems and four control methods. It was felt that, though comprehensive and easily understood, the work did not adequately address duct system heat and volume losses for the purposes of this work. Additionally, they used a constant "1.1" term for the specific heat divided by the specific volume in the loads computations. Since the specific volume is a function of both the temperature and moisture content, the constant term could introduce as much as a 5% error. It was decided to use the variable specific volume. Knebel's methods for determining the temperature rise of the supply and return air due to the fans were employed. The equations used were derived from fan law relations.[4,5]

This work was conducted on the premise that facility energy consumption could be characterized by considering the facility usage schedule, space loads and system and equipment performance separately. Given this, facility energy performance could be expressed in the form:

$$E=(Q_{SPACE})*(F_{SCHEDULE})*(F_{SYSTEM})*(F_{PLANT}) \qquad (1)$$

where

E=Facility Energy Consumption(Btu/yr)

Q_{SPACE}=Aggregate Space Load(Btu/yr)

$F_{SCHEDULE}$=Schedule Factor

F_{SYSTEM}=HVAC System Factor

F_{PLANT}=Plant Factor

Previous research on the first term on the right hand side of equation (1) has been accomplished. The objectives of the team who conducted the research on Q_{SPACE} were to develop standard facility energy performance targets which would "result in cost-effective, energy efficient design of commercial buildings."[6] The results of their work included an equation for Q_{SPACE} basically in the form:

$$Q_{SPACE}=f(\text{CONDUCTION})+f(\text{SOLAR GAIN})+f(\text{LIGHTING})+f(\text{OTHER}) \qquad (2)$$

In this equation, f(OTHER) consisted of miscellaneous internal loads and infiltration and ventilation loads. And though the f(OTHER) term was sometimes very high, it was not within the scope of their research to study it. Also, Q_{SPACE} referred to overall consumption rather than merely aggregate space load. In order to arrive at some consumption values, a specific HVAC system had to be chosen. The system chosen was the constant volume terminal reheat system. Both the DOE2.1C and BLAST energy prediction programs were used in developing the large data base required to accomplish the parametric studies used to determine the coefficients in equation (2) above. At the time this report was written, teams from Battelle Pacific Northwest Laboratory and the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), had begun follow-on work to the above mentioned project. The program developed by this research

should provide a tool to assist in the determination of both the f(SYSTEM) and f(SCHEDULE) terms of Equation (1).

The ASHRAE Handbook of Fundamentals was consulted on numerous occasions during the period of this research.[7,8] The procedures contained within were followed, at least in part, in the determination of humidity ratios and certain enthalpy values. The tables included in the Psychrometrics chapter formed the base for many of the curve fit equations used in this work.

CHAPTER 2

METHODOLOGY

2.1 ASSUMPTIONS

A number of assumptions had to be made in the process of defining the model to reduce program running time. In making these assumptions, care was taken to structure the program to allow the user to modify the values of constants and the coefficient of curve fit equations to adapt analyses to particular situations simulated.

First, it was assumed that the facilities modeled would have an above ceiling return plenum which contained the supply duct system. It was also assumed that the plenum temperature was uniform and that no return duct would be utilized. Heat flow into/out of the plenum was assumed to occur through exterior walls and the ceiling. Air leakage and heat transfer from the supply duct system, heat gain from the back surface of lighting fixtures and return air flow were also balanced in determining plenum temperature.

It was difficult to quantify the error, if any, associated with the assumption of uniform temperature throughout the plenum. This is due to the plethora of situations which are possible for duct sizing, exterior wall area, obstructions in the plenum and zone set point temperatures, among others. Except in extreme cases, the primary factor defining the plenum temperature is the air returning from the individual zones. Since the individual zone set point temperatures are usually the same, or at least very nearly the same, the air entering the plenum from the zones at different points should also be at the same temperature.

It was assumed that small temperature gradients in the plenum will have little effect on an average hourly return air temperature and overall heat transfer to the duct system. A plenum temperature which was not uniform would effect the heat transfer to the supply duct system at specific points, but in normal operation the effect on the overall duct heat transfer should be negligible.

For situations where this program is to be used to simulate multiple story facilities, the program will calculate one average plenum temperature. If, in the particular instance, this is not accurate enough, the facility can be modeled as having multiple systems. Each system would service a single story and the resulting system loads would be added together.

Moist air consists of a mixture of dry air and slightly superheated water vapor. The water vapor behaves as an ideal gas for the temperatures and pressures encountered in HVAC operations.[9] The enthalpy of the moist air is defined as

$$h=c_{PA}*T+W*h_{g} \qquad (3)$$

where

h=Enthalpy(Btu/lbm)

c_{PA}=Specific heat of dry air at constant pressure(Btu/lbm-°F)

T=Temperature of air mixture(°F)

W=Humidity ratio(lbm of water/lbm of dry air)

h_g=Enthalpy of saturated steam at air mixture temperature(Btu/lbm)

Small errors result from using a constant value of specific heat and from the fact that while the value of h_g is for saturated vapor, the water vapor in the mixture is usually slightly superheated.[9]

Air mixture velocity was assumed to be constant along major segments of the supply duct. The "maximum trunk duct velocity" term called for as input at the beginning of the program was used for the determination of the trunk duct cross sectional area using equation (4) below.

$$A_D=CFM/V \tag{4}$$

where

A_D=Cross sectional duct section area(ft^2)

CFM=Volumetric flow(ft^3/min)

V=Maximum duct velocity(ft/min)

The "maximum zone branch duct velocity" input does the same for the branch ducts. The purpose for using the term "maximum" was because in VAV systems operating at off-design conditions, the velocities would be lower. For the VAV system option, the average hourly velocities are considered as constant for the hour, with new values established for each hour.

The values for the specific heats of dry air and water vapor were assumed to be independent of temperature. This is a reasonable assumption in the range encountered in normal HVAC applications. The value of the specific heat of dry air in the temperature range of 50°F to 110°F was determined to be 0.236585Btu/lbm-°F ($\pm$0.4%) and the value of the specific heat of vapor was determined to be 0.448833Btu/lbm-°F ($\pm$0.7%).[10] The error that would be introduced in assuming this constant specific heat value would be less than 2% for temperatures as low as -10°F.

The supply duct system was assumed to be made up of round ducts for the purposes of calculating duct surface area, temperature rise, and heat loss. No provision was made for modifying equations for the use of square, rectangular, or flat oval ducts. For heat loss purposes, it was assumed that the

entire exterior surface area of the duct was exposed to the plenum air.

It was also assumed that all of the air leakage from the supply duct system to the plenum occurred in the immediate vicinity of the supply fan. Therefore, the temperature of the air leaked to the plenum was taken to be the air temperature leaving the fan. This volume of lost air contributed directly to the reduction of, or increase in, the temperature of the plenum air. It was calculated as an addition to the air volume required to satisfy the individual zone space loads. Using the assumption that the zone loads were completely satisfied, at least with respect to air volume delivered, insured that the most conservative approach to duct leakage was taken. This procedure forced the maximum amount of air volume to cross the coils. The total temperature rise in the supply duct system is usually 5°F or less for most systems. Since the greatest percentage of leakage in a duct system occurs at the supply fan, it was assumed that the error associated with lumping all the leakage there did not warrant incrementally leaking a percentage of the volume along the duct sections. Also, if the user were to calculate duct leakage incrementally, he would be required to provide much more information. The benefits in increased accuracy of assuming distributed losses could not justify this added level of input.

Duct leakage is input by the user as a percentage of the total volume of air crossing the coils, as opposed to a percentage of the total volume of air required to satisfy the individual zones loads. An incorrect user input would result in a 1% lower total air volume crossing the coils for each 1% of duct leakage estimated. However, the overall error in the coil load calculation could end up being much less during many periods of operation. For example, when the system is operating in the cooling mode and the minimum amount of outside air is being used,

the reduced volume of air crossing the coils due to an incorrect leakage estimation is offset by the increased mixed air temperature entering the coils. This is due to the increased plenum temperature associated with the lower volume of cool air leaked.

Another thing to note with the duct leakage term is that the user inputs a percentage loss (%/100) which remains constant throughout the twenty four hour simulation. For the constant volume terminal reheat and cycling system modeled this should be the case, but for the VAV system there may be slight variations due to velocity and pressure changes in the duct system over the twenty four hour period. Without much more detailed information on the specific system components and duct system simulated, this difference would be difficult to quantify. However, these effects will tend to cancel each other, producing approximately the same percentage duct leakage. Again, it was decided to take the conservative approach and use the maximum leakage at design conditions.

A supply fan will always be used and therefore, the user must input supply fan data. The user can, though, opt to use, or not use a return fan. With either fan, the choice of whether or not to locate the fan motor in the air stream is left up to the user.

2.2 LIMITATIONS

Since the program was developed to produce results quickly, using simplified techniques, it does have limitations which must be deemed acceptable by the user. Absolute accuracy in predicting energy consumption was not the major criteria by which simulation techniques and equations were chosen. However, every attempt possible was made to include all contributions to system load. This should be evident by the above mentioned assumptions.

The strength of this work lies in its ability to identify the primary performance characteristics, relative to systems and controls choices.

The procedure used in determining the temperatures and loads in this program is based on time averaging. All final and intermediate results are average hourly values. Therefore, it has problems when the conditions of a simulation are highly time dependent. It is understood that massive facilities can cause a substantial thermal lag in the transmittance of space loads to the system and that the space set point temperature is maintained only within a throttling range. It is assumed, though, that the loads and temperatures input to this program are based on the dynamic characteristics of the spaces and that the net hourly values are representative of real loads averaged over the time period. The premise for the values calculated here is that the average hourly values are equal to the net time dependent energy rate.

The equations used also have no capability to correct for deviations in barometric pressure or altitude. They assume standard barometric pressure of 14.696 psia at sea level. For most applications, it was determined that the increased accuracy realized by the inclusion of corrections for such deviations could not justify the added complexity of the program.

The major limitation of the program is in the number of systems and controls choices available. It is felt that the options included represent the most common in practice, but it is understood that there are many others which could be included if the time allowed. The program is set up to allow future inclusion of additional capabilities.

2.3 GOVERNING EQUATIONS

As stated earlier, fundamental energy equations were used in the determination of loads and associated variable

quantities. It is assumed that moist air behaves as an ideal gas and steady state conditions prevail throughout the system. The following sections of this chapter describe the algorithms used which are common to all HVAC systems modeled. System or control unique computational methods will be discussed in subsequent chapters.

The load across the cooling coil is calculated assuming no work is done on the air through the coil and that there are negligible changes in kinetic and potential energy through the coil. With the above assumptions, the energy equation reduces to

$$Q_{COIL}=m_T*(h_{ENTER}-h_{EXIT}-(W_{ENTER}-W_{EXIT})*h_F) \quad (5)$$

where

Q_{COIL}=Total load on coil(Btu/hr)

m_T=Total mass flow rate(lbm/hr)

h_{ENTER}=Enthalpy of moist air entering the coil(Btu/lbm)

h_{EXIT}=Enthalpy of moist air exiting the coil(Btu/lbm)

W_{ENTER}=Humidity ratio of moist air entering the coil(lbm of H_2O/lbm of dry air)

W_{EXIT}=Humidity ratio of moist air exiting the coil(lbm of H_2O/lbm of dry air)

h_F=Enthalpy of saturated H_2O at the leaving coil dry bulb temperature(Btu/lbm)

Note in the above equation that Q_{COIL} is defined as being positive for cooling loads and negative for heating loads. Also, note that all humidity ratios will be expressed in units of pounds mass of water per pound mass of dry air. The last term on the right hand side of the equation (i.e. $(W_{ENTER}-W_{EXIT})*h_F$) results when liquid water is condensed out of the air stream. This term is usually

appreciably smaller than the other terms and is often neglected. It was however, included in the analysis and did not increase run time. The equation for h_{f} was developed from data contained in the ASHRAE Handbook of Fundamentals using a curve fitting program.[7] The temperature range of application used for this value was 45°F-110°F.

For the enthalpy terms (i.e. h_{ENTER} and h_{EXIT}), Equation (3) was used to account for the sensible and latent components of the coil load. To determine these enthalpy values, the air mixture dry bulb temperature and humidity ratio needed to be calculated. Downstream of the coil, the temperature condition was set by the control method chosen by the user. It was either fixed by input or calculated based on space and associated system loads. The exiting humidity ratio was fixed either by the assumed maximum relative humidity exiting the coil, as input by the user, or the entering coil conditions and the temperature of the air leaving the coil.

On the entering side of the coil, the mixed air temperature and mixed air humidity ratio were calculated based on mass averages of return and outside air. Temperature and humidity values varied considerably due to economizer operation. The following mass balance equation was used to obtain the entering or mixed air temperature:

$$T_{MIX}=(1-PTOA)*T_{R}*(v_{MIX}/v_{R})+PTOA*T_{OA}*(v_{MIX}/v_{OA}) \qquad (6)$$

In this equation, PTOA is defined as the ratio of outside air volumetric flow (CFM) to total or mixed air volumetric flow (CFM). The appropriate specific volumes were then used to convert volumetric flow rates to mass flow rates. The exact same method was used for the calculation of the entering or mixed humidity ratio (W_{MIX}). Iteration was required as the specific volume, v_{MIX}, term is dependent on both T_{MIX} and W_{MIX}.

2.3.1 Mass Flow Rate Calculations

The total mass flow term in Equation (5) is defined as the sum of the mass flows required to satisfy each of the zone loads plus the flow which is lost to the plenum due to leakage. It is calculated as the volumetric flow divided by the specific volume. The specific volume was allowed to vary as both a function of the temperature and humidity ratio of the moist air. The volumetric rate of air flow was constant in any duct section or across the coil due to the previous assumption of constant velocity. The equation used for calculating specific volume as a function of the temperature and humidity ratio was

$$v=0.0252112*(T+459.7)*(1.0+1.6078*W)(ft^3/lbm) \qquad (7)$$

This equation assumes standard atmospheric conditions. The temperature term, T, is in units of °F.[8]

2.3.2 Humidity Ratio Calculations

The zone humidity ratios (W_z) were calculated with the latent component of the space load input by the user and the following equation

$$W_z=W_{Lc}+Q_{Lz}/(m_z*h_{fgz}*60) \qquad (8)$$

where

W_{Lc}=Humidity ratio leaving coil

Q_{Lz}=Latent space load(Btu/hr)

h_{fgz}=Latent heat of H_2O at the leaving coil temperature(Btu/lbm)

m_z=Required zone mass flow rate(lbm/min)

60=time conversion(hours to minutes)

The solution of this equation was also iterative due the dependence of m_z on W_z. A curve fit equation was used for h_{wez} from data contained in [7].

Under the assumption that the air entering the plenum mixes uniformly both in temperature and humidity, a mass balance was accomplished again to determine the return air humidity ratio. The sum of the contribution from each of the zones was added to the amount of air which entered the plenum due to duct leakage. The conditions of the leakage air were considered to be the same as the conditions of the air leaving the supply fan. The mass balance equation needed to be manipulated because of the dependence of the return air specific volume on the return air humidity ratio (see Equation (7)). The final form of the equation which was used is as follows

$$W_R = SMPLFY/(1.0-1.6078*SMPLFY) \tag{9}$$

where

W_R=Return air humidity ratio

$SMPLFY=0.0252112*(T_R+459.7)*([\sum(CFM_z*W_z/v_z)]$
$+(\%\ \text{duct loss})*CFM_{LCT}*W_{LC}/v_{LC})/CFM_R$

T_R=Return air temperature(°F)

CFM_z=Zone volumetric flow rate(ft^3/min)

CFM_{LCT}=Total volumetric flow rate leaving the coil prior to duct leakage(ft^3/min)

CFM_R=Total return volumetric flow rate including duct leakage

In the above equation, the two volumetric flow rates, CFM_{LCT} and CFM_R, are equal, but the corresponding mass flows are not. This is due the probable difference in the leaving coil and return specific volumes, which depend on temperature and water content.

Prior to the computation of the mixed air humidity ratio, the outside air humidity ratio had to be computed. Using the input data for outside air wet and dry bulb temperatures, the methods contained in the 1985 ASHRAE Fundamentals Handbook were followed to compute the outside air humidity ratio.[8] Curve fit equations for the enthalpy and saturated enthalpy values were used instead of the approximate values given. To compute the humidity ratio of the air mixture leaving the coil, ASHRAE methods were again used with a curve fit equation for the saturated humidity ratio obtained from data contained in [8] and the user input of assumed relative humidity leaving the coil. All curve fit equations are contained in the program source code of Appendix D. The information on relative humidity needed to use these equations was obtained from the user input data.

2.3.3 Duct Temperature Change Calculations

Two main factors cause the temperature of the supply air to change from the exit of the coils to the point at which it is delivered to the space. The first of these is the heat gained from or lost to the plenum and the second is the heat gained due to the supply fan. Therefore, the temperature of the air mixture being supplied to the zone, prior to any reheat or induction, is defined by

$$T_{ZSUP}=T_{LC}+\Delta T_{SF}+\Delta T_{TD}+\Delta T_{SD} \qquad (10)$$

where

T_{ZSUP}=Zone supply air dry bulb temperature(°F)

T_{LC}=Leaving coil air dry bulb temperature(°F)

ΔT_{SF}=Supply air dry bulb temperature change due to supply fan(°F)

ΔT_{TD}=Supply air dry bulb temperature change due to heat loss/gain in trunk duct(°F)

ΔT_{BD}=Supply air dry bulb temperature change due to heat loss/gain in branch duct(°F)

In equation (10), the ΔT_{TD} term is the sum of all the changes in trunk duct sections upstream of the particular zone branch. These duct section temperature changes are described below.

Plenum to duct section heat transfer

As the air mixture flows through the supply duct system to the zone, it is heated or cooled due to the temperature difference between the supplied air and the plenum. Using the methods contained in [11], with the approximation that ΔT is equal to the temperature difference between the plenum air and the supply air in the duct at any point along the duct

$$dQ=m_T*c_{PM}*d(\Delta T)=U_D*\Delta T*dA_S \tag{11}$$

where

dQ=Heat transfer to or from the duct(Btu/hr)

U_D=Effective duct "U" value(Btu/hr-ft²-°F)

dA_S=Differential surface area(ft²)

$d(\Delta T)$=Differential change in temperature in the duct(°F)

c_{PM}=Specific heat of the air mixture (Btu/lbm-°F)

Separating the variables and carrying out the integration yields a temperature in the duct which varies exponentially. In an effort to further reduce the computational time of the simulation, the change in the temperature of the air in the duct for a section of

the supply duct was approximated as ΔT_D. The temperature difference between the plenum and the air mixture in the supply duct was approximated as being the plenum air temperature minus the initial duct section air temperature minus half ΔT_D. Therefore, the overall heat transfer was approximated as

$$Q=m*c_{PM}*\Delta T_D=U_D*A_s*(T_{PL}-(T_o+\Delta T_D/2)) \quad (12)$$

where

T_{PL}=Air temperature in the plenum(°F)

T_o=Initial duct section temperature(°F)

Using Equation (12) for the determination of ΔT_D produces accurate results, within 1% of those found by using Equation (11), except for very long duct sections (greater than approx. 600 ft.) or very small flow rates (less than 40 ft^3/min). For flow rates and duct sections usually encountered in practice, the difference was found to be on the order of 0.1%.

The estimated length of branch and trunk duct runs is input by the user. For the determination of the rise or fall of temperature in the trunk duct, a section is defined as the length of duct from the exit of the supply fan to the first zone branch or the distance between zone branches. A branch duct section is defined as the length of duct between the trunk duct and the point of entry into the zone of the supply air. The branch duct section can be approximated as the distance to the reheat coil or VAV box, if one is used in the system simulated. If multiple branch ducts are present for a particular zone, only the longest one should be input as will be described later in the DATA INPUT section of Appendix C.

Fan heat transfer

The second manner in which heat is transferred to the air stream in the duct is through the supply fan. For the constant volume systems modeled, the cycling and terminal reheat systems, the temperature rise due to the fan was considered a constant value whenever the system was operating. For the VAV system, part load factors were used and will be discussed in the section on FAN CONTROLS in Chapter 3.

For fans operating at the design point, the fan horsepower is given by

$$\text{Fan HP}=CFM_F*P_T/(n_F*6350) \tag{13}$$

where

CFM_F=Volumetric flow across fan(ft^3/min)

P_T=Total pressure(inches of wg)

n_F=Fan efficiency

6350=Conversion factor(ft^3*inches of wg/min-hp)

The fan horsepower is divided by the motor efficiency to obtain the motor horsepower. To calculate the temperature rise of the air mixture, the methods of [3] were followed and equation (14) below was used.

$$\Delta T_{SF}=(\text{Fan HP})*2545/(n_M*m_T*c_{PM}) \tag{14}$$

where

n_M=Motor efficiency

2545=Conversion factor(Btu/hr-hp)

The program developed also allows for the case where the motor is not contained within the air stream. In this case, the program simply sets the value of the motor efficiency to 1.0.

The program assumes the use of a supply fan and will not allow the user to opt otherwise. On the other hand, it does allow the user the option of whether or not a return fan is employed. If a return fan is used, the temperature rise in the return air mixture due to the return fan is calculated in the exact same manner.

2.3.4 Plenum Temperature Calculations

As mentioned earlier in the section ASSUMPTIONS, heat transfer into or out of the plenum was allowed to occur from many different sources. The predominant source is the air returning from each zone. Additionally, the air leaked from the supply duct system, transmission through the ceiling panels and supply duct system, a fraction of the lighting energy and transmission through the exterior envelope are included.

The contributions from the individual zones and the leaked supply air are determined by the rate at which the air enters the plenum, its specific heat and its temperature. The lighting energy and the fraction which enters the plenum are both input by the user. The heat contribution to the plenum is simply the lighting energy multiplied by the fraction entering the plenum. Thus, the user has the ability to allow no lighting energy to enter the plenum directly. The user must take care in the input of lighting energy because the program assumes that the sensible space load input includes, in part, a lighting energy component. This component is, of course, the fraction of lighting energy which is not directly released into the plenum.

Heat is transferred to or from the plenum through the zone ceiling panels using the equation

$$Q_C=U_C*\sum(A_Z*(T_{PL}-T_Z)) \qquad (15)$$

where

Q_C=Heat transferred through the ceiling(Btu/hr)

U_C=Effective ceiling "U" value (Btu/hr-ft^2-°F)

A_Z=Zone area(ft^2)

T_Z=Zone temperature(°F)

A limitation to the program is that only one effective "U" value is allowed for all the ceiling area in the facility simulated. If various ceiling "U" values are present in the facility, it is recommended the user take a weighted average value, based on the products of zone areas and changes in temperatures between the zone set point and the plenum.

To determine the total heat transfer contributed by transmission through the duct system, Equation (12) was used on each section of duct. Then, the results were summed and added to the overall plenum temperature equation.

The final component of heat gain or loss to the plenum is the contribution from the environment through the exterior envelope. The user inputs this value based on an assumed plenum temperature, which is also an input or can be defaulted to a value of 81.0°F. Inputting this load as a function of an assumed plenum temperature allows the calculation of the load based on an actual plenum temperature calculated by the program. The load is calculated using

$$Q_{PW}=Q_{PWA}*(T_{OA}-T_{PL})/(T_{OA}-T_{PLA}) \qquad (16)$$

where

Q_{PW}=Actual plenum wall load(Btu/hr)

Q_{PWA}=Plenum wall load based on assumed plenum temperature(Btu/hr)

T_{PLA}=Assumed plenum temperature(°F)

The accuracy of this method depends to a large degree on the closeness of the initial assumed plenum temperature estimate. Small changes in calculated plenum temperatures from the assumed value will result in only negligible errors in this load and even less error in the iterated calculation of a new plenum temperature. The primary error here is the assumption that the load to the plenum from the outside is instantaneous. That is to say, there is no thermal capacitance in the exterior wall. However, as the environment load is small relative to other plenum loads, it did not seem worthwhile to require dynamic calculation.

For systems simulations which do not include the use of a return fan, the plenum and return air temperatures are synonymous. If a return fan is used, the return air temperature is simply the change in temperature across the return fan added to the plenum temperature.

2.3.5 Supply Air Temperature Calculations

To satisfy the sensible portion of the load in each space, air must be supplied to the zone at a specific dry bulb temperature. This is the case, no matter which HVAC system or controls strategy is employed. Since each zone will have a different sensible load, and thus require a different supply air temperature, the required temperature for each zone must be calculated. The sensible load is input by the user and is used in the following equation to determine the required supply temperature.

$$T_{ZR}=T_Z-Q_{ZS}*v_{RS}/(CFM_Z*c_{PA}*60) \qquad (17)$$

where

T_{ZR}=Required zone supply air temperature(°F)

Q_{ZS}=Zone sensible load(Btu/hr)

v_{RS}=Required supply air specific volume(ft^3/lbm)

The difference between the required supply air temperature and the actual supply air temperature must either be made up by reheating the air (explained below in the section ZONE REHEAT CALCULATIONS) or by changing the temperature of the air coming off the coils. Note also, that the Q_{sz} term is defined as being a positive quantity for cooling loads and a negative quantity for heating loads. Therefore, as would be expected, a lower than space set point air temperature is required for spaces exhibiting a cooling load and vice versa.

2.3.6 Zone Reheat Calculations

Some HVAC systems or controls strategies used dictate that the temperature coming off the coils must remain fixed or that the temperature be set based on a controlling zone. In these cases, the temperature of the air being supplied to some zones and the air mixture temperature required to satisfy these spaces' sensible load are different. If the temperature is higher than what is required, a decision must be made to either lower the air temperature coming off the coils, increase the volume of air entering the space, or to allow the space air temperature to rise above the zone set point temperature and thus, not satisfy comfort criteria. On the other hand, if the air mixture temperature being supplied is lower than what is required to satisfy the space load, the temperature coming off the coils cannot usually be raised because the set point is being dictated by the needs of another zone. Here, either the HVAC system must be shut off, which is the case in the cycling system modeled, or some type of supply air reheat must be used so the zone temperature does not fall appreciably below the zone set point.

For constant volume, non-cycling systems, reheating is accomplished by raising the temperature of the primary air supplied to the required supply air temperature. This is done with the use of a reheater which is usually located near the zone and services only one particular zone. Only heating is accomplished in the systems modeled; there is no provision for humidification. The equation used to calculate the energy required to reheat the air stream is

$$Q_{RHZ}=60*CFM_{Z}*c_{PA}*(T_{ZR}-T_{ZSUP})/v_{S} \qquad (18)$$

where

Q_{RHZ}=Zone reheat load(Btu/hr)

v_{S}=Supply air specific volume(ft^3/lbm)

The zone reheat should always be a positive quantity. If the program output shows a negative zone reheat load, it means the temperature of the supply air is too high and there is no other way (i.e lowering the leaving coil air temperature or increasing the volumetric flow) the program can satisfy the cooling load. In this case, the user can make the decision whether to reduce the temperature of the air mixture coming off the coils or to allow the temperature in the zone to rise above the zone set point temperature.

In the VAV system modeled, the air exhausted from the zone can be reused and even reheated if necessary. Reheating supply air or changing its temperature off the coils may not always be necessary because the CFM_{Z} term is allowed to increase or decrease between maximum and minimum values input to satisfy the load. In some cases, the primary air cannot be reduced enough and the temperature of the supply air must be changed. The particular VAV system modeled in this research is a system equipped with the ability to reuse zone return air for reheating

the zone. If the temperature of the air being supplied is too cool and the volume of air reaching the zone is already at the minimum value required for ventilation, some of the air normally exhausted to the plenum is reused to warm the supply air with the use of inductors. These inductors also have a limited flow rate. This is due to either the physical size constraints or because of the probable increased maintenance considerations of a large inductor fan and motor. Therefore, when the maximum amount of return air is reused and the load is still not satisfied, the reused air is reheated and mixed with the primary supply air to reach the desired temperature.

CHAPTER 3

SYSTEMS AND CONTROLS

3.1 HVAC SYSTEMS

The constant volume Terminal Reheat system, Variable Air Volume system with Induction Type Reheating, and a Cycling system were chosen as the systems to be modeled for this research. These three systems were selected to provide the user with a choice of systems that can be energy efficient in the design of new facilities or which are in wide use in existing facilities. Of course, with the plethora of systems and subsystems used in practice today, arguments could be voiced for virtually any system. Therefore, the final decision came down to choosing three systems which were completely different in concept and which would not generally be used for the same facility. The user would then be able to see the variation in coil loads for the same basic space loads in the same geographic location. Additionally, because these three systems were all single duct systems, many of the same or similar equations and programming logic could be employed in the program. This allowed for minimal computational redundancy and thus, reduced time to obtain results.

3.1.1 Terminal Reheat System

The constant volume HVAC system modeled is shown in Figure 3.1. The system has the ability to service one to fifty separate zones. Each zone has its own space sensible and latent loads, set point temperature, air flow rate and lighting energy. Additionally, each zone is equipped with a zone reheater which will reheat the entire primary air supply to the temperature

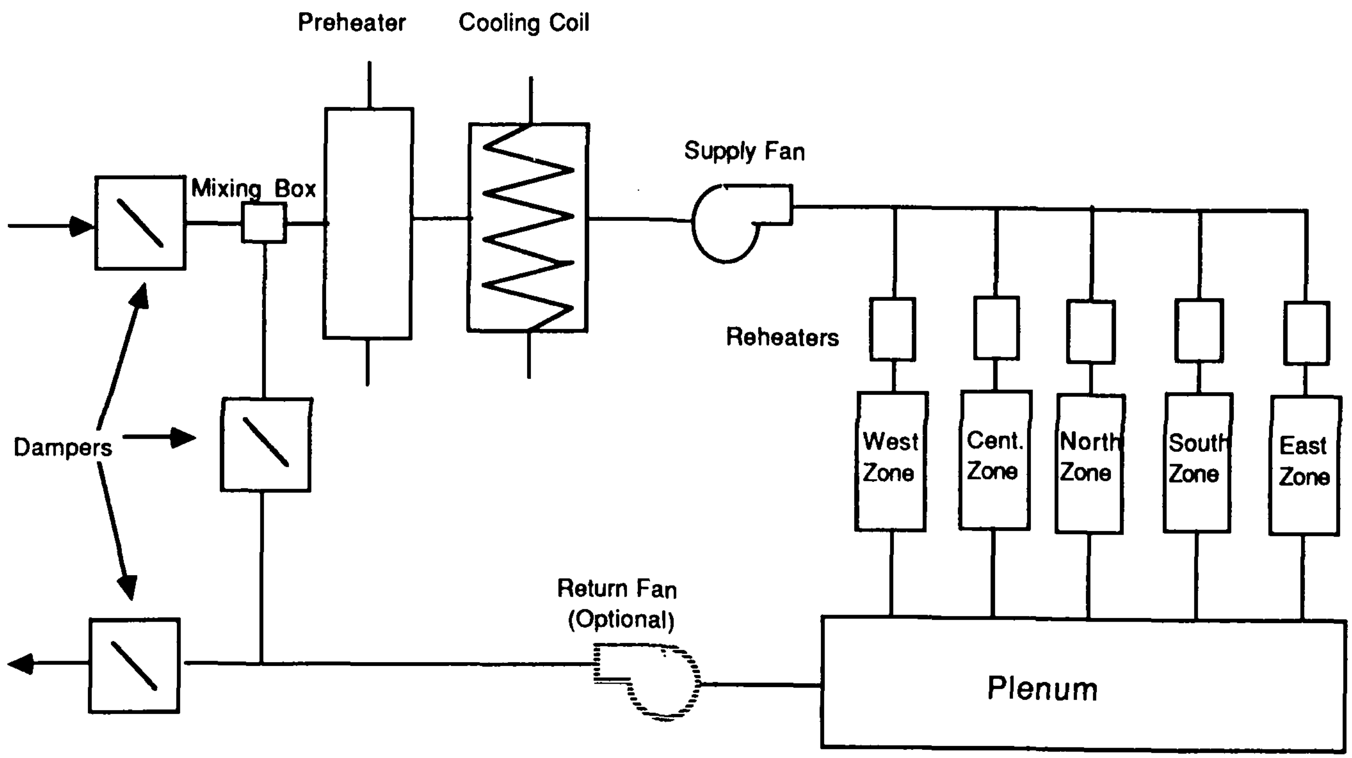

Figure 3.1-Terminal Reheat System

required to satisfy the total space load. It is assumed that the reheaters, as with all equipment, can handle any load which may arise during the twenty-four hour period of simulation. The system includes a set of cooling coils, a preheater, and a supply fan. It was assumed that either the cooling coils or the preheater would work to condition the mixed air entering, but not both simultaneously. No ability to humidify the air was included. The speed of the supply fan and the volume of air it was moving were considered constant. Of course, if the loads or schedule dictated the system be shut off, the supply fan could also be shut off.

Since the user inputs the volume of air which is being supplied to each zone, and thus the total volume entering the fan, the fan could be used as a dual speed fan which sets one speed for winter (heating) operation and one speed for summer (cooling) operation. Additionally, the system was set up to allow for the option of using a return fan, an economizer, or both. All the controls strategies described below in the section CONTROLS STRATEGIES were applicable to this system. The air exhausted from each zone was modeled as returning through a ceiling plenum.

3.1.2 Variable Air Volume(VAV) System

The VAV System modeled (Figure 3.2), like the Terminal Reheat System, has the ability to service up to fifty separate zones. Again, each zone could have different sensible and latent space loads, set point temperatures, air flow rates and lighting energies. The difference in input arises from the fact that the volume of air which can be supplied to each zone is variable. Therefore, the user inputs both a minimum and maximum value for volumetric flow into each zone. The maximum value must remain constant for the entire period of simulation, but the minimum is allowed to vary based on ventilation and occupancy schedules.

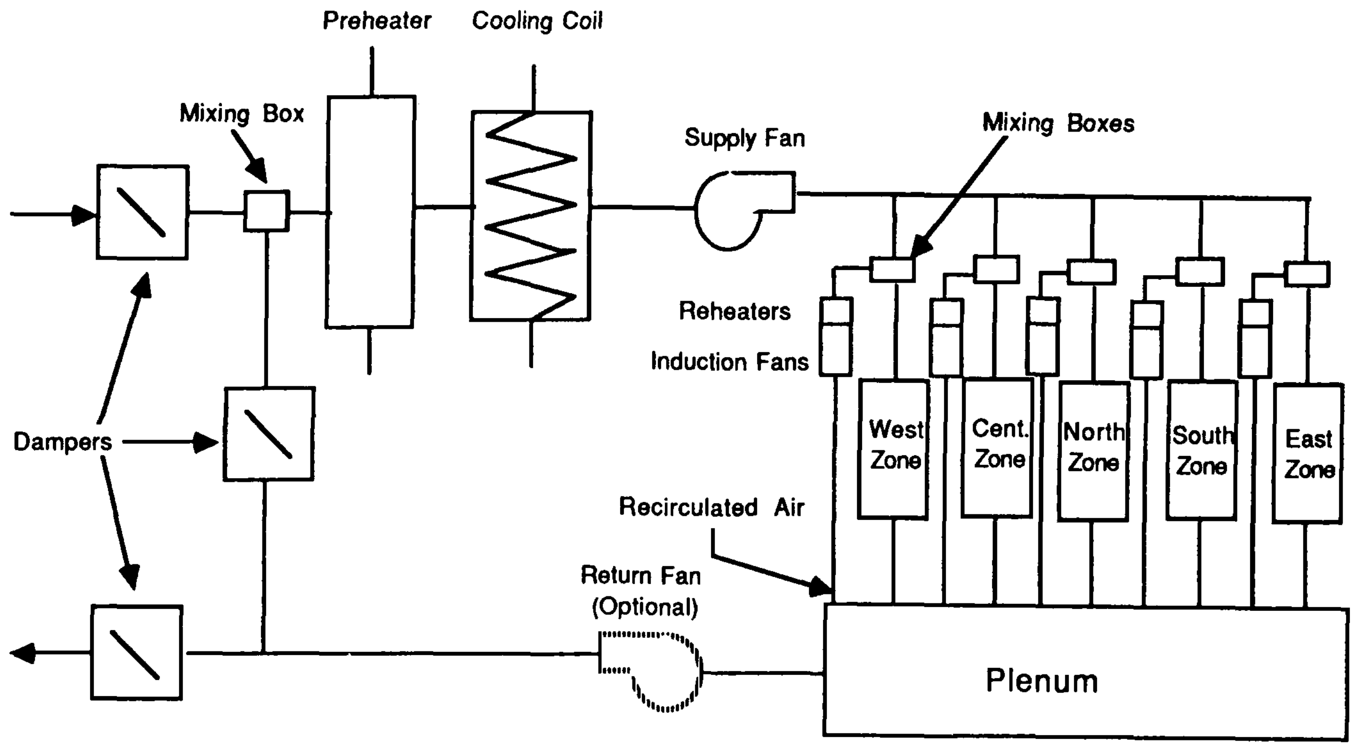

Figure 3.2-Variable Air Volume(VAV) System with Induction

With this system, the space load can be satisfied one of four ways. The temperature of the air mixture coming off the coils, the primary air volume being supplied to the zone and the secondary or induced air volume can all be changed. Additionally, the secondary air can be reheated. This is accomplished in the following manner. First, the temperature of the air mixture is set by the particular control method chosen with the maximum volumetric flow rates. If the program determines that the zone will be over-cooled, it reduces the volume of primary air supplied until the load is matched. When the volume or primary air has been reduced to the minimum value and the zone still is experiencing over-cooling, the program sets the primary air to its minimum value and begins to mix induced air until this mixed air temperature is equal to the required zone supply air temperature. In some cases, the maximum amount of induced air will be used and the resulting air mixture will still be too cold. Here, the program sets the volume of induced air to the maximum and then heats it so when it is mixed with the primary air, previously set to its minimum value, the resulting mixed air temperature is equal to the required zone supply air temperature.

The VAV system is equipped with a set of cooling coils and a preheater, which cannot be run simultaneously. An optional economizer and return fan are also included in the model. The difference between the fan control for constant volume systems and the VAV system is that the volume of air which is passing through the supply and return fans can be varied. Because the user has to have knowledge of minimum flow rates for each zone, it was assumed that the fan used could handle both the minimum and maximum total flows input. With this in mind, no fixed minimum flow rate through the fan was identified and no default value included. Fan control methods for the VAV system are described in the section FAN CONTROLS.

As mentioned above, this system can reheat a portion of the zone return air and mix it with the primary supply air to provide the correct air mixture temperature which will satisfy the space loads. This is accomplished with the use of a fan and motor set near the zone. This equipment can only recirculate a fixed amount of the return air back into the zone. Size, noise, maintenance and comfort all have to be considered when selecting the size of this equipment. The maximum flow rate through this equipment will be needed as input to the simulation program.

3.1.3 Cycling System

The Cycling System modeled (Figure 3.3) is different from the other two in three main ways. First, the system is designed to be able to shut down many times within an hour if the loads so dictate. Of course, when it is running, it does so at constant volume of air mixture to the zone. The second main difference is that the system modeled can only service one zone. Without a complex duct and damper system and a sophisticated controls system, the loads in many of the zones would have a good chance of being under-satisfied, over-satisfied, or even under- and over-satisfied in the same hour. The third difference occurs because of the concept of the system. Since it cycles on and off so as to exactly meet the load, there is no need for reheating the supply air. As with the other two HVAC systems modeled, the cycling system has the ability to use all the economizer options and controls strategies. It also employs the same zone specific input data as the terminal reheat system.

3.2 CONTROLS STRATEGIES

Most, if not all, facilities which employ a central HVAC system to provide either comfort or process heating and cooling are equipped with some type of controls scheme. Some schemes may

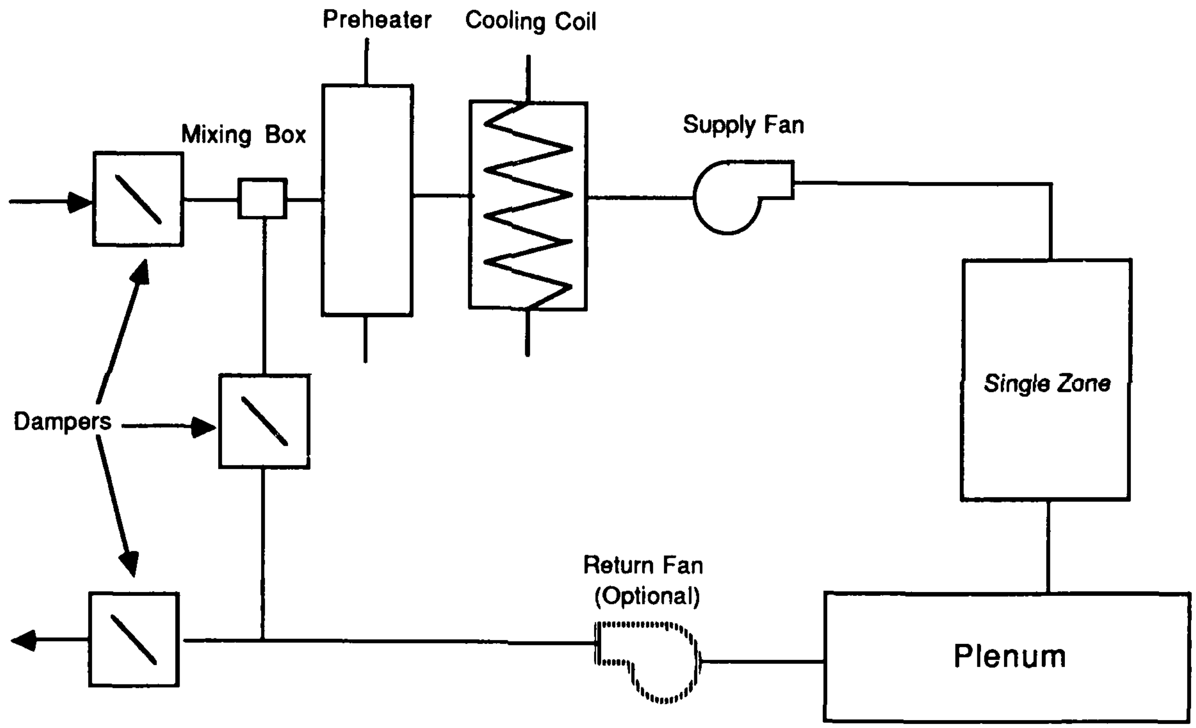

Figure 3.3-Cycling System

be as simple as fixing the dry bulb air mixture temperature exiting the coils to some minimum temperature as prescribed by the peak design loading. Others may be much more complex, providing for tight control for both humidity and temperature and for differing schedules. Additionally, in the interest of energy efficiency, some facilities may be designed with multiple HVAC systems servicing only portions of the facility, each with its own control strategy. For the purposes of this research, three of the more common controls strategies used to set the temperature of the air mixture leaving the coils were chosen to model. These included the fixed set point method, the zone controlled method and the outside air controlled method and are described below.

3.2.1 Fixed Set Point Control Method

The fixed set point control method allows the temperature of the air mixture exiting the coils to be set to any constant temperature as determined by the design or facility engineer. The set point may be chosen based on the design engineer's calculation of the peak loading. Though this method may be the best way to ensure that all loads are satisfied all the time, it is also may provide for the most wasted reheat and cooling energy.

The set point may also be chosen based on the facility engineer's experience with both the facility's occupancy and equipment schedule and the weather patterns of the particular geographic location. In the latter case, the set point may be changed seasonally, monthly or even more frequently. This control method model works the same way for all three HVAC systems modeled.

It was not the objective of this research to make decisions on how or how often to employ the controls strategies modeled. Therefore; the fixed set point control method modeled

allows the set point to be varied each twenty four hour simulation. No default set point value was included in the program because, though many systems are designed to operate in the range of 55°F for the exiting air mixture temperature in the cooling mode, each situation is different and should be the decision of the user.

With the use of a fixed set point control method, no matter what logic goes into the set point decision, there is always the chance of setting the exiting temperature either too high or too low. The program, as written, has no provisions for checking to see if the set point chosen is optimal or for suggesting a better one. It was not possible to include such a check, due to the fact that the program is only a one day simulation and a recommendation based on only a twenty-four period may not reflect what is actually required for year round or seasonal operation. A quick check to see if the temperature chosen is too high to satisfy the individual zone cooling loads can be accomplished, though, because of the sign convention used in the calculation of zone reheat. A negative zone reheat encountered in the output to the program shows that the load in the particular zone will not be satisfied during the entire hour and that the zone set point temperature input will probably not be maintained.

3.2.2 Zone Controlled Method

The second controls strategy modeled uses the zone with the load requiring the lowest leaving coil temperature as the controlling zone. It sets the hourly coil leaving temperature based on this zone. The model works differently for each system modeled.

For the constant volume Terminal Reheat system, once the temperature has been determined based on the controlling zone, the

air temperature being supplied to each zone is then calculated based on duct losses. Since the coil leaving air temperature is determined based on the controlling zone, there is no reheat load associated with that zone. The reheat load for the remaining zones, if any, is calculated using the method described in the section ZONE REHEAT CALCULATIONS. There is an exception to this procedure. The program has a maximum default leaving coil temperature of 68°F, if any of the zones is calling for cooling. If the program determines that the required leaving coil temperature is greater than this default value, it will set the temperature to this maximum value. All zones will then require some amount of reheat energy, even the controlling zone.

In the case of the VAV system, the program initially sets the volumetric flow for each zone to it maximum. The required zone air supply temperature is then calculated as described in the section SUPPLY AIR TEMPERATURE CALCULATIONS of Chapter 2 and the controlling zone identified. This ensures that the highest coil exiting air temperature will be selected which still satisfies all the zone loads for the particular hour simulated. If the overall facility load is a heating load, it will ensure that the lowest temperature is selected. Once the temperature is selected, the volumetric flow for the controlling zone is kept set at its maximum and the volumetric flows for the remaining zone are calculated. Since the total air volume will probably be reduced in this step, the intermediate values of plenum and duct section temperatures are recalculated. A new leaving coil temperature is then calculated, based on this new reduced air volume. Finally, the volume of induced air and possible reheat load for the remaining zones is computed. As with the Terminal Reheat system, there is one exception to this procedure. When the maximum allowable leaving coil temperature is

reached, the volumetric flow to each zone is reduced, even in the controlling zone.

When this control method is used with the cycling system, the exiting coil temperature is calculated based on being able to exactly satisfy the hourly load. Because of this matching, the system must run the entire hour to satisfy the load. In essence, it resembles a single zone, constant volume Terminal Reheat system with no reheat energy required. Though in practice the Cycling system is not used with this type of control method, the simulation may provide some insight into the fixed temperature which should be selected. Since this system is modeled as a single zone system, when the maximum allowable leaving coil temperature is reached the only way the system can balance the load is to shut down. In this case, this control method behaves like the fixed set point method.

The maximum allowable leaving coil temperature was included as a default value in the program. This value can be changed by the user if latent load control is not critical. When the value is set too low, the zone controlled method will behave like a fixed set point method during most hours.

3.2.3 Outside Air Controlled Method

The outside air controlled method of control sets the leaving coil air temperature based on a set temperature determined by the user. The program, in the subroutine SETTLCC, opens and reads a permanent file which has been previously set up. This file contains sets of outside air dry bulb temperatures and corresponding leaving coil air dry bulb temperatures. The input of data to this file is described in Appendix C, in the section SYSTEMS/CONTROLS OPTIONS. In reading the file, the program compares the hourly outside dry bulb temperature being simulated with all the outside dry bulb temperatures contained in the file.

When it finds an outside temperature in the file which is within ±0.5°F, it then reads the mated leaving coil air temperature and sets the leaving coil temperature for the hour being simulated to this value.

If no outside air dry bulb temperature within ±0.5°F can be found in the file, the program will print the message, "Outside air temperature encountered in hour X (i.e.XX.X°F) is beyond the range of your control schedule. Either your control method or schedule must be changed.", on the screen. The required user actions are contained in Appendix C.

It should be noted that the schedule need not be entered prior to every simulation. The file has the capability of holding 150 pairs of temperature values. It can be set to hold all the data required by a specific location or facility for all situations. Though it is expected that a range of ±(1 or 2)°F for the outside versus leaving coil temperatures is as tight as would be needed, especially in the cooling mode, the smaller range was included for the special situations requiring such. It was felt that, since the file need only be set up once, the added input associated with the smaller ΔT would be minimal.

3.3 ECONOMIZER OPTIONS

The concept of an economizer system is to make maximum use of the ability to mix zone return air and outside air to minimize the load on the coils. This is accomplished while staying within the prescribed minimum levels of outside air required for ventilation purposes. In some situations, the use of an economizer may actually allow the coils to be shut down totally and thus, the facility is cooled for "free". Economizer systems are becoming more widely used in the designs of new facilities. In fact, the inclusion of some type of economizer system was required by ASHRAE Standard 90A-1980 for new commercial facility

designs employing HVAC system larger than 5,000 cubic feet per minute. This minimum size has been recommended to be further reduced to 3,000 cubic feet per minute in a proposed revision to the standard.[6] The basic concept behind any economizer is as described above, but there are different methods of controlling the amount of outside air which will be mixed with the return air. The two common methods of economizer control, dry bulb temperature and enthalpy, were chosen for use in this research and are described below.

The program also includes the option to maintain the percentage of outside air used at a constant value, input by the user. This was included because in smaller systems other factors, like economics, may preclude the use of an economizer system. Additionally, there are many facilities in use today with no economizer system and exclusion of this option would limit the use of the program.

3.3.1 Temperature Economizer Control

The control of an economizer system using a comparison of the dry bulb temperatures of the outside and return air mixtures is an efficient and usually economical means of conserving facility HVAC energy. With the coil leaving air temperature fixed by load conditions, the load on the coils, and thus the energy used, is directly related to the inlet conditions. Therefore, if the temperature of the mixed air entering the coils is closer to the exiting temperature, the load on the coils will be lower. For dry climates or where humidity is not a factor this is always the case. This can be seen by Equations (3) and (5).

As mentioned earlier, a minimum amount of outside air is usually required for ventilation purposes. This value is input by the user and is based on facility occupancy schedules or other environmental factors. The dry bulb temperature controlled

economizer modeled works by mixing the incoming air with the following instructions. If the outside air has a dry bulb temperature greater than 62.5°F, the percentage of outside air allowed is set to the minimum level set by the user. If both the outside air and return air temperatures are higher than the required leaving coil temperature, then the percentage of outside air is set to the minimum if the outside air temperature is greater than the return air temperature. It is set to a maximum if the outside air temperature is less than the return air temperature and less than the maximum allowable outside dry bulb temperature. There are also many times when the required leaving coil temperature is between the outside and return air temperatures. In these cases, equation (19) is used to determine the optimal mixing percentage.

$$\text{Percent Outside Air} = (T_R - T_{LC}) * 100 / (T_R - T_{OA}) \qquad (19)$$

The specific volume ratios do not come into effect in this equation because the outside air percentage was defined as the ratio of the volumetric flows, which do not change with air temperature or humidity ratio.

The default value of 62.5°F was chosen as the maximum outside air temperature allowed because, if the air were saturated at this temperature, it would correspond to conditions in the individual zones of 78°F and 60% relative humidity. The maximum temperature was included in the program as a default value. If latent load control is not a concern, or if the climate is inherently dry, it can be increased during input.

3.3.2 Enthalpy Economizer Control

There are many times where humidity plays as important a role in the energy consumed by an HVAC system as dry bulb

temperature does. In these cases, as shown in Equation (5), the difference in enthalpy, both the sensible and latent components, between the entering and exiting air mixture controls the load on the coils. Therefore, the energy consumed would be minimized if the enthalpy of the air entering the coil was as close as possible to the enthalpy of the air leaving the coil. This is the principle behind an enthalpy controlled economizer system. As can be seen by observing a psychrometric chart, there are times when the enthalpy controlled economizer would make a different choice than the dry bulb controlled economizer on the percentage of outside air used by the HVAC system. These cases are shown graphically in Figure 3.4. With the leaving coil and return air conditions depicted by A and B, respectively, the dry bulb controlled economizer would choose a maximum percentage of outside air if the outside dry bulb temperature was less than the return air dry bulb temperature, T. This includes both region W and region Y. Conversely, the enthalpy controlled economizer would choose to minimize the percentage if the outside air condition was in region Y. This is due to the high humidity level of the outside air in this region. The other region where the two control differ is when the outside air conditions are contained in region Z. Here, the dry bulb controlled method would set the outside air percentage to a minimum; whereas, the enthalpy controller would maximize the use of outside air due to its low humidity level.

The enthalpy controlled economizer system model makes use of the outside air dry and wet bulb temperatures, which are input by the user, to compute the enthalpy of the outside air. This is accomplished with Equation (3). The humidity ratio, W, in this equation was calculated following the procedures described in the section HUMIDITY RATIO CALCULATIONS. The curve fit equation for the humidity ratio, saturated at the wet bulb temperature, can

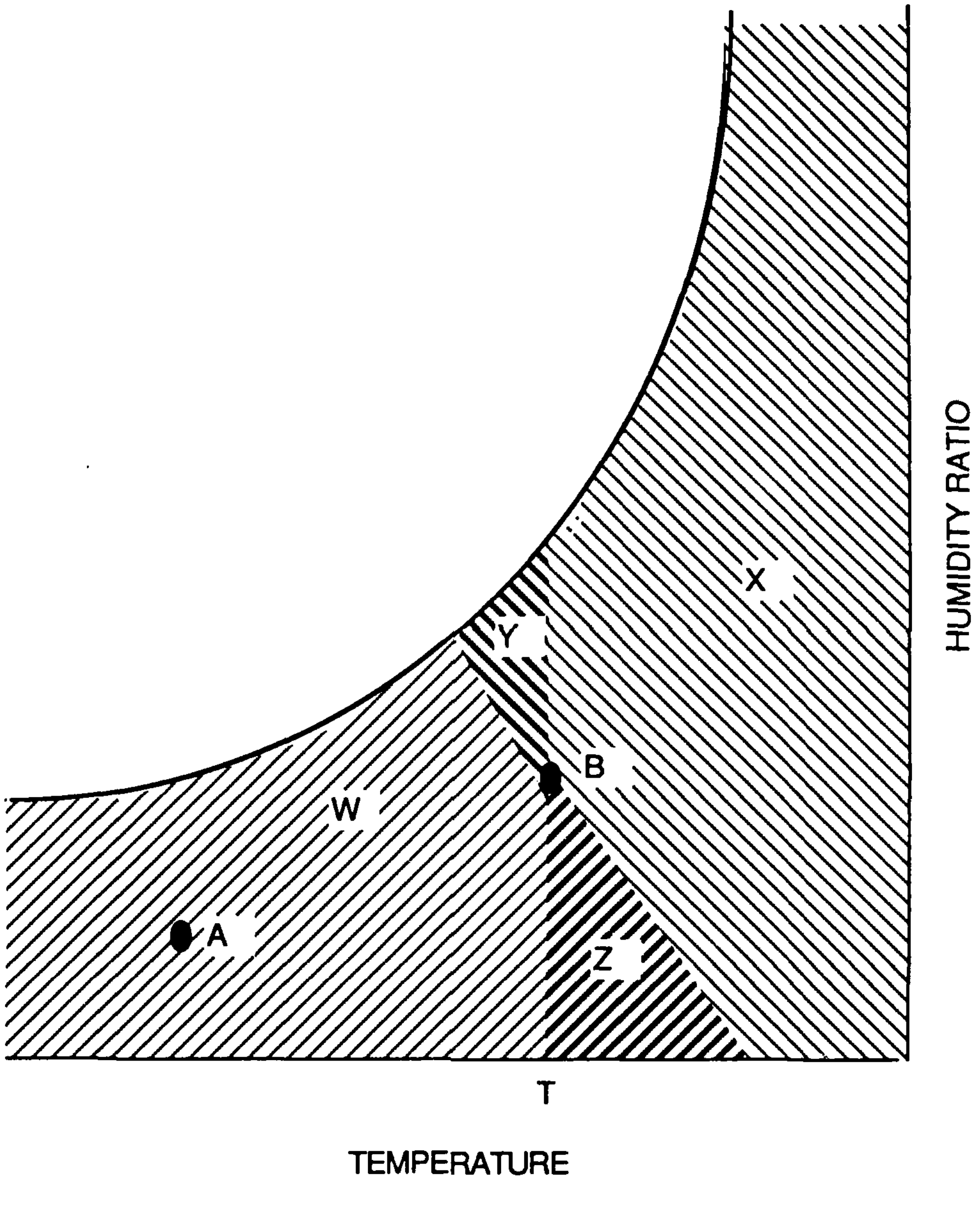

Figure 3.4-Economizer Control Variations

be found in the program source code of Appendix D. The data used in the development of the equation was taken from reference [8]. The enthalpy of the return air was calculated using Equation (9) and the return air temperature.

Similar logic to the dry bulb temperature controlled economizer described above was used for the instructions to the enthalpy controlled economizer. For example, in the case where the enthalpy of both the outside and return air mixtures are above the leaving coil enthalpy, if the outside air enthalpy is greater than that of the return air, the percentage of outside air used is set to the minimum value allowed. For the case where the leaving coil enthalpy is between the outside and return air enthalpies, Equation (20) below is used by the program to calculate the percentage of outside air which will provide "free cooling".

$$\text{Percent Outside Air}=(h_R-h_{LC})*100/(h_R-h_{OA}) \qquad (20)$$

where

h_R=Return air enthalpy(Btu/lbm)

h_{LC}=Leaving coil enthalpy(Btu/lbm)

h_{OA}=Outside air enthalpy(Btu/lbm)

With this control method, there is no maximum enthalpy level of outside air which causes the percentage of outside air to be reduced. Use of this method insures an optimum level of mixing.

Figure 3.5 shows how the enthalpy controlled economizer performs. In region A, the percentage of outside air remains at a minimum value fixed by environmental constraints. Region B, describes the case where the leaving coil enthalpy is between the return and outside air enthalpies. Here, the two air conditions are mixed so that the enthalpy of the resulting mixture is equal to the leaving coil air enthalpy. This is called "free-cooling". When the return air enthlapy is greater than the outside air

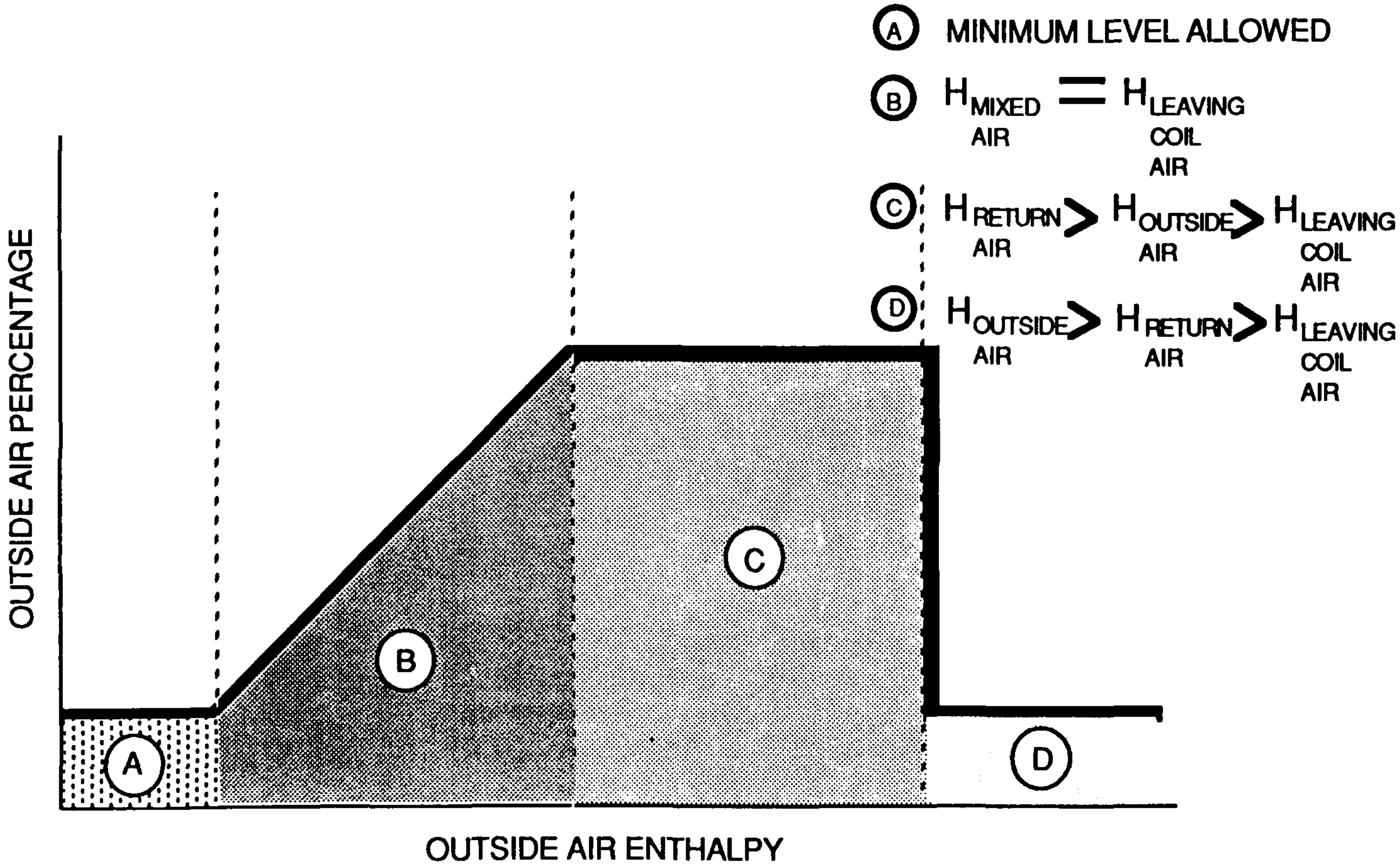

Figure 3.5-Conditions for Enthalpy Economizer Operation
(Note: H = Enthalpy)

enthalpy and the outside air enthalpy is greater than the exiting coil enthalpy, the percentage of outside air is set to its maximum as shown in region C. The final case is where the outside air enthalpy is greater than the return air enthalpy, which is in turn greater than the leaving coil enthalpy. Here, the outside air is reduced to the minimum limit as shown in region D.

One of the user inputs is the assumed maximum relative humidity exiting the coils. This value should usually be between 95% and 100%, depending on the type of cooling coil employed. If the latent loads in the facility are such that the assumed saturation level is not reached, the coils are considered dry. This means that the coils are performing only sensible cooling and that the humidity ratio exiting the coils is the same as the humidity ratio entering the coils. In this case, the enthalpy controlled economizer is actually performing like the dry bulb temperature controlled economizer described above. Because of the sequence of operations in the program code, namely that the final exiting coil humidity ratio for dry coil operation is computed after the percentage of outside air has been determined, it was more efficient to use the dry bulb control rather than iterate one more t e.

3.4 FAN CONTROL

The method by which the volume of air through a fan is controlled during part load operations can drastically change the associated temperature rise of the air. For constant volume systems, like the terminal reheat and cycling systems, control is not a factor because the flow through the fans is always at or very near the design volume. The only difference would be if the fan had a two speed motor for summer and winter operations. In this case, the methods described in the section FAN HEAT TRANSFER of Chapter 2 could still be used for both summer and winter

operation. The user would be required to know the fan and motor efficiencies at both speeds.

This is not so for the VAV system modeled. In this system, the volume of air changes every hour and is usually not near the design point. Because of the continuous change in air volume, there has to be some control on how the fan moves the changing load. Four methods of control were chosen for use in the program. They included a variable speed motor, the use of inlet dampers, the use of discharge dampers and a cycling fan.

For off-design operations, Equation (21) was used to calculate the temperature rise of the air mixture due to the fan. (The method for determining the temperature rise at the design air flow was described in the section FAN HEAT TRANSFER.)

$$\Delta T_{FAN(OFF-DESIGN)} = \Delta T_{FAN(DESIGN)} * FFLP/PLR \qquad (21)$$

where

PLR=Fan Part Load Ratio(Actual CFM/Design cfm)

FFLP=Fraction of Full Load Power

$=a+b*PLR+c*PLR^2+d*PLR^3$

To use this method for off-design fan performance and control, the coefficients a, b, c and d must be known for the particular fan control method selected.[3] These coefficients were defined by a curve fit of specific fan data. Rather than requiring the user to input these coefficients or spend a large amount of time developing them from fan manufacturer's data, it was decided to use the coefficients used in the DOE 2.1B program. If these are not satisfactory, the user has the option of changing them. The four coefficients for each of the four methods of control were taken from the DOE 2.1B energy prediction mainframe program.[1] The coefficients are default values and the program allows for

change of each of them during its input phase. Specific values of the coefficients can be seen in the program code, Appendix D.

Most fans operate extremely inefficiently at part load ratios of less than about 20%. In the development of the program, it was assumed that, since the user was required to input both the maximum and minimum total air flow rates, the fan selected would operate satisfactorily within the limits specified by the user. This was assumed to allow for the maximum amount of flexibility in equipment selection, but care should be taken so as not to unknowingly simulate the running of either the supply or return fan at unacceptably low flow rates because erroneous results may occur.

CHAPTER 4

PROGRAM IMPLEMENTATION

The next phase of this work was to develop the computer code to carry out the calculations. To fulfill the project's primary objective, the code had to be accomplished so as to be able to run on a microcomputer with minimal time required for results. It also had to be as simple to use as possible and had to allow the greatest flexibility for system parameter variation. Another underlying objective was to structure the code so that additional systems, control strategies, schedules and other options could be included at a later time.

4.1 HARDWARE/SOFTWARE USED

The IBM Personal Computer AT was chosen as the development tool. IBM equipment was selected to allow for the widest dissemination of this program. At the time of this work, it was determined that the greatest percentage of microcomputers in use in practice today were either IBM microcomputers or microcomputers which are compatible with the IBM. With the use of this microcomputer, a single twenty-four hour simulation, employing a night time setback schedule with little or no nighttime loads, required on the average approximately fifteen to twenty seconds to produce results. No simulation accomplished during the period of the research ever took over a minute. Of course, the use of this program with less capable microcomputers could require much more time to complete simulations.

FORTRAN 77 was the programming language used to write the code for this program. FORTRAN 77 was chosen to allow transport of the program to main-frame equipment and to other

microcomputers with a minimum of effort. Also, since one of the objectives of this work was to provide a program which could be used by as many people as possible, it was felt that FORTRAN 77 was one of the more familiar computer languages and would allow more users to make the source code changes which might be necessary to fit specific need. Additionally, it was envisioned that this program would someday be linked together with a space load program, equipment component performance programs and probably an economics program in an overall energy use program. The use of FORTRAN 77 would facilitate easier meshing of the overall program parts than some of the other computer languages.

4.2 DATA INPUT OPTIONS

A significant amount of input is required to set up the program for an initial simulation run. Because of this and because it is assumed that inexperienced users may be making the inputs, great care was taken to develop a format for input which is "user friendly". This procedure provides for easy, stand alone data editing and update. Additionally, since one of the main objectives of this research was to develop a tool for parametric studies, the data is stored in a manner so as to provide for flexibility in the use of the data files. The input which is to be stored to a permanent file is separated into three main categories; weather and zone independent data, zone unique data and control data. All simulations require the initiation of the weather and zone independent data permanent file. It includes information on outside dry and wet bulb temperatures, plenum envelope load and assumed relative humidity exiting the coils. The second category of files which is required by each simulation contains the zone unique data. For the constant volume systems, the data is contained in one file consisting of space sensible and latent loads, zone set point temperature, required air volume

rate, and lighting load. For the VAV system, the air volume data in this file is input as the minimum air volume rate allowed. The maximum primary and secondary, or induced, air volume rates are input as a separate file.

The third category of permanent files is only used when the control strategy is chosen as outside air controlled. For this case, a schedule of outside air temperature versus corresponding leaving coil temperature must be input. The program will search this file during each hour of the simulation. It will look for an outside air dry bulb temperature($\pm 0.5°F$) which corresponds to the one input above in the weather and zone independent file. It will then set the leaving coil temperature for the particular hour based on the leaving coil temperature found in this file.

All the above mentioned files are stored to a hard or floppy disc and can be reused without reinputting the data for each simulation.

Another way that flexibility is enhanced is the inclusion of options to alter the default constants and systems configuration each time a simulation is run. These selections are not stored in a permanent file and are usually made with a single alphanumeric character input or selection of a variable value.

A detailed description of the input routine is provided in Appendix C. It details every step needed to be accomplished by describing exactly what will be seen on the computer screen and what information will be required during input. Appendix C can be used as a user's manual during input or as a prior reference to insure all data which will be required for input is available.

4.3 PROGRAMMING AND EXECUTION LOGIC

4.3.1 Initial Programming Decisions

During the initial stages of this research, many basic decisions had to be made with respect to how the code for the computer program was to be written. These included which computer language would be used, how the code should be sectioned, how input should be obtained and how to develop the code in a manner which allowed for the greatest clarity and ease of update.

The decision was made to use FORTRAN 77 as the computer language for the code. As mentioned previously, it was chosen mainly because of its flexibility.

Separate subroutines were used for every major calculation or set of calculations required for intermediate results. The program is made up of a driver main program, which is also the input/output routine, and twelve subroutines. The code is contained in Appendix D. It was felt that the use of many subroutines would reduce the time required for future revisions, the time required for compilation, and the time required during the initial program development. The names of the subroutines show the major intermediate or final result calculated within. Most of the subroutines are very short and revisions required to include additional systems or controls options should be able to be accomplished easily.

Since subroutines were used, different variables had to be passed into and out of each one for use between them. This could have been accomplished one of two ways; by passing the variables as arguments in the CALL statements or by using COMMON statements. It was thought that COMMON statements would provide the vehicle for minimizing errors associated with the passage of variables. Furthermore, because all subroutines did not need to pass all the same variables, it was initially felt that the COMMON

statements would section the variables passed and allow easier and quicker observation of the variables used by each subroutine. As the program developed though, their use for the purpose of clarity diminished. The variables contained in each COMMON block were revised many times during the program's development so as to reduce the number of statements used by each subroutine. Finally, in the interest of time, this effort was discontinued. It was determined that further revision would contribute only minimally to added clarity. These block statements, though not optimally divided, still provided the sectioning which was initially desired. The problem in using the COMMON statement is that when future revisions are made to a COMMON statement, care must be taken to include the change in each subroutine which has the same five letter designated COMMON statement.

The final major decision which had to be made prior to beginning code entry was the method of data input and storage. Two methods were evaluated for possible use. The first method was to have the user be required to set up one or more permanent files for input data with the use of whatever editing tool was available and to provide a user's input manual which described each variable set to be input. The program would then call and read this file during its execution. This would have made the code contained in this work much shorter, but would have made the input of the large amount of data much more laborious for the user. Specific instructions would have had to be provided to ensure the file was formatted correctly so as to allow for proper reading by the program. Changing data for parametric studies would have required opening the permanent file(s), making the changes and then rerunning the program. It was felt that this method contained a greater potential for data error, input ambiguity, user confusion and most of all, it would require more of the user's time. Additionally, it would have required the user to have an editing

program compatible with this program. The main reason that the method described in Appendix C was chosen was because it provided a straightforward, stand alone method for obtaining results. Nothing besides the executable file of the program would be required, except the data itself. The method chosen may be a little slower during initial input, but changing only specific variables or options should be much quicker and provide for only a small chance for error.

4.3.2 Program Execution

Upon completion of data input, the program is begun by typing HVAC. It should be noted that the computer keyboard should be in the "CAPS ON" mode because the program does not recognize lower case letters for some of the options. The programs begins by calculating the cross-sectional areas for all branch ducts and trunk duct sections using Equation (4). In the case of the VAV system, the maximum volumetric flow rate is used. The design flow in each trunk duct section is determined by subtracting off the flow for each zone at the branch. Then, after initializing all "flags" and required data fields, it begins the twenty-four hour simulation.

Ten "flags" or checks are used in the program which allow the program to check if an intermediate result has been initially calculated, a maximum or minimum has been reached or an iteration has been been completed. They are designated IFLAG1 through IFLAG9 and IWCHK and their specific purpose is described in the variable table of Appendix B.

For the first iteration of the first hour of each simulation, the temperature of the plenum is set to the assumed plenum temperature. This value is obtained from the default constants table (i.e. 81°F or the temperature it was changed to during input). The temperature of the air mixture leaving the

coils is set to 55°F, unless the fixed set point control method is chosen. In this case, it is set to the input value. The return air temperature is set to the assumed plenum temperature. In hours two through twenty-four, these temperatures are set to their respective values for the previous hour. For the first iteration of every hour, the flow rate to each zone is set to its maximum when the VAV system is being simulated. The cycling system is initially assumed to be running 80% of the time for the first iteration each hour. If the program determines there is no load to all zones, it completes only one iteration and proceeds to the next hour. A comment stating that the system was not running during that hour will be contained in the results. The program completes one iteration in this case because it will need previous hour values for some of the variables, as described above, in the following hour.

The program executes by performing three main iteration loops, depending on the system and control strategy selected, each hour. It iterates on the flow of air delivered to each zone, the leaving coil air temperature and the plenum air temperature. These loops are described below.

The innermost loop is used with the VAV system only. It calculates the required flow rate to each zone based on the load in the zone and the temperature of air being supplied. This loop is contained in the subroutine CFMREQD. The air flow rates are calculated differently, depending on the control strategy chosen. When the control strategy is either the fixed set point or outside air controlled method, the flow rates to each zone are decreased from their maximum values to exactly match the load. If there is more than a 1% difference in the flow to any zone from the previous iteration, the total flow to all zones is recomputed and a new plenum temperature is calculated. The new plenum temperature is calculated because, even though the air temperature

off the coils remains the same with these control strategies, the heat lost to the plenum changes and thus, the temperature of air being supplied to each zone changes. This is a result of the increased or reduced air flow in the duct system and through the fan. In the program, this recomputation of the plenum temperature is actually accomplished by telling the program to recalculate the leaving coil air temperature (i.e. setting IFLAG2 equal to zero). It is done this way because, since the plenum temperature has already been calculated in its own subroutine prior to the total flow rate, it will not be recalculated if it has not changed more than 0.1% from the previous value. Therefore, results could be produced using an inaccurate plenum temperature. New flow rates are calculated again, using the new plenum temperature and thus, new supply air temperature.

If the flow rate to any zone reaches a minimum allowed, zone return air is mixed with the supply air, at the plenum temperature. It is reheated if necessary as described in the section VARIABLE AIR VOLUME SYSTEM of Chapter 2. When the zone controlled method is chosen with the VAV system, the first pass through the air flow loop just determines the zone requiring the lowest leaving coil temperature at the maximum air flow rates. This zone is marked and remains the controlling zone for each iteration during the hour. The flow rate to this controlling zone will remain at its maximum. The flow rates to the remaining zones will be iterated upon as described above. Since both supply temperature and flow are allowed to vary with this configuration of system and control, one of them had to be fixed by the program. It was decided that fixing the flow rate to its maximum value would produce the highest temperature of air off the coils (or the lowest temperature in the heating mode) and thus, the lowest load on the coils. Of course, this reduction in load would be nearly offset by the increased air flow. With this method and the use of

an economizer, the range in which "free cooling" could occur would increase. The exception to this procedure occurs when the temperature leaving the coil is determined to be greater than the maximum allowed. Here, the leaving coil air temperature is set to the maximum allowable and the flow rates to all zones are reduced. In this case, the program works as if the fixed set point control method had been chosen for that hour.

The middle iteration loop calculates the temperature of the air mixture leaving the coils and is contained in the subroutine SETTLCC. Iteration is only required when the zone controlled method is selected. For all three systems simulated, the controlling zone is determined and marked prior to entering the SETTLCC subroutine. This is accomplished in the TSZREQD subroutine by calculating the supply air temperature required to exactly satisfy the space load and then subtracting from this the temperature of the air which is actually supplied. The lowest resulting value, whether it be positive or negative, is marked. Physically, this resulting value is the temperature difference for the zone requiring the least reheat, or the most additional cooling. Once the controlling zone has been determined, the SETTLCC subroutine takes the controlling zone's required supply air temperature and subtracts the temperature rises occurring in the duct system due to the supply fan and trunk and branch duct heat exchange with the plenum. This becomes the new estimate for the leaving coil temperature. If the calculated value differs from the previous iteration by more than 0.1%, then the two temperatures are averaged and another iteration is accomplished. This is done for a specific plenum temperature, between plenum temperature iterations.

The outermost loop iterates on the temperature of the air in the plenum. The calculation of the plenum temperature is accomplished in the subroutine TPLENUM. The equations used and

methods followed were discussed previously in the section PLENUM TEMPERATURE CALCULATIONS. As with the leaving coil air temperature, if the calculated value of the plenum temperature differs from the previous iteration (or initial assumption) by more than 0.1%, then the values from the previous and current iteration are averaged and another plenum temperature is calculated.

When the cycling system is simulated, the program must determine the system's running time per hour. If the zone controlled method is chosen, the program assumes the system will always be running because only a single zone can be simulated and the zone control method chooses a leaving coil temperature which exactly satisfies the hourly loads. This will be the case unless the maximum allowable coil temperature is reached. For the other two control methods, usually only one or two iterations are required to determine this running time within 1%. During the iteration, if the calculated value differs from the previous or assumed value by more than 1%, the previous value is set equal to the calculated value and another iteration accomplished.

CHAPTER 5

DISCUSSION OF RESULTS

The purpose of this chapter will be to demonstrate some of the capabilities of the program developed. This will be accomplished, in part, with the use of a space loads data base obtained from an execution of the DOE 2.1B mainframe facility energy simulation program. There are many different combinations of system, control strategy, economizer and fan control options which could be used for case studies. In the interest of space, only two case studies will be presented here. The first study compares the performance of the Terminal Reheat (TRH) and VAV systems with varying control strategies. It is accomplished under both summer and winter conditions. Also, the same two systems will be studied using autumn data for different economizer option choices. The results of these analyses are discussed below.

A medium sized, one-story, 10,000 ft^2, office building in Phoenix, Arizona was chosen as the basis for the simulations. This facility contained four, cardinally oriented, exterior zones and an interior zone. East and West zones measured fifteen feet deep by seventy feet wide. North and south measured fifteen feet deep by one hundred feet wide. The central zone was a seventy foot square. The HVAC system was modeled as being situated on the west wall of the facility and thus, the duct system runs began there. The decision to use this facility was based solely on the fact that there was already an existing loads data base.[12]

Information pertaining to the individual zones and weather data was extracted from the output of a DOE 2.1B simulation. A total listing of the DOE 2 simulation output is not presented as only the loads data are used. The DOE 2.1B output

which has been used as input to this program is listed in the input permanent files. A complete sample input listing for one of the simulations is presented in Appendix A. Three separate input permanent files, described in the section DATA INPUT OPTIONS, for the VAV system are also included. All remaining non-system data used in the input (i.e. plenum wall load and maximum zone and induction volumetric flow rates) were developed either from calculations performed with available loads information or, in the case of the flow rates, by running trial and error program simulations.

It is emphasized again that no attempt will be made to compare the results of this program with those of the DOE 2.1B or any other energy prediction program. The objective of this work is to provide the ability to characterize the performance of one HVAC system, coupled with its control strategy option, relative to the performance of other possible combination system and control choices.

5.1 CASE STUDY ONE-CONTROL STRATEGIES

This case study was presented to show how the program depicts the performance of both the VAV and Terminal Reheat systems with varying control strategies. The fixed set point (FSP) and zone controlled method (ZCM) of control were selected. All the variables listed below were used and kept constant for the simulations contained in this study.

----Duct "U" value set at 0.2 Btu/hr-ft^2.

----All other default constants unchanged.

----Dry bulb economizer option chosen. (The amount of outside air would have remained at a minimum no matter which economizer choice was selected for the summer weather conditions. For the winter weather conditions, 100% outside air was used for all hours except the first morning hour.)

----The minimum percentage of outside air allowed set at 10%.

----Summer and winter weather data (i.e. wet and dry bulb temperatures) from Phoenix, Arizona used.

----Assumed maximum relative humidity off coils set at 98%.

----Plenum envelope load based on 800 Btu/hr per °F temperature difference between plenum and outside air.

----Zone sensible and latent loads, set point temperatures and lighting energy from DOE-2.1B used.

----Total design pressure drop across supply fan set at 3.5 inches of water.

----Supply fan design efficiency set at 75%.

----Supply fan motor design efficiency set at 95%.

----Total design pressure drop across return fan set at 0.5 inches of water.

----Return fan design efficiency set at 70%.

----Return fan motor design efficiency set at 90%.

The differences in the input for the two systems came in the areas of zone volumetric flow rates and control of the fans. For the Terminal Reheat system simulations, since a constant flow rate was input for each zone, constant speed supply and return fans were simulated. Both the supply and return fans for the VAV system were simulated as variable speed motors. The default coefficients contained in the program were not changed for these fans. The maximum allowable zone flow rates for the VAV system simulations were determined using a fixed set point for the coil discharge temperature. The CFM rate which corresponded to each zone peak was then selected as its maximum. A value equal to 75% of the maximum primary rate was selected for the maximum induction rate in each zone of the VAV simulations. As it turned out, no

induction was necessary for either VAV summer simulation. For the winter runs, recirculated air was used. However, the maximum available flow was never reached. The minimum volumetric flow rates for the VAV system were determined from the occupancy schedule and minimum rate allowed on a per person basis.[12] The maximum VAV rates were also used as the basis for the constant volume flow settings of the TRH simulations.

Two sets of simulations were conducted for summer and two for winter. The first set consisted of both systems assuming the fixed set point method of control. The second set assumed the zone control reset method was used. Results of these simulations are shown graphically in Figure 5.1 and Figure 5.2.

5.1.1 Summer Simulations

As was expected, the resulting load on the coils for the VAV system was found to be significantly less than for the TRH system using either method of control. The energy wasted due to the increased coil load with the Terminal Reheat system was not the only reason for additional energy use with this system. Using the zone controlled method, the leaving coil temperature had to be set low enough to satisfy the controlling zone in each hour. This meant that all other zones had to reheat the incoming supply air to maintain the desired comfort level. With the fixed leaving coil set point, the results were even worse. In this case, the temperature leaving the coils had to be set low enough to satisfy the zone with the highest load during the entire simulation period. Therefore, there was only one zone, and only for two hours, which did not require the supply air to be reheated. The other source of wasted energy in the Terminal Reheat system was in the higher volume of air which had to pass through the fans. Since fan motor energy does not appear explicitly in the simulation, the additional fan energy used did not show explicitly

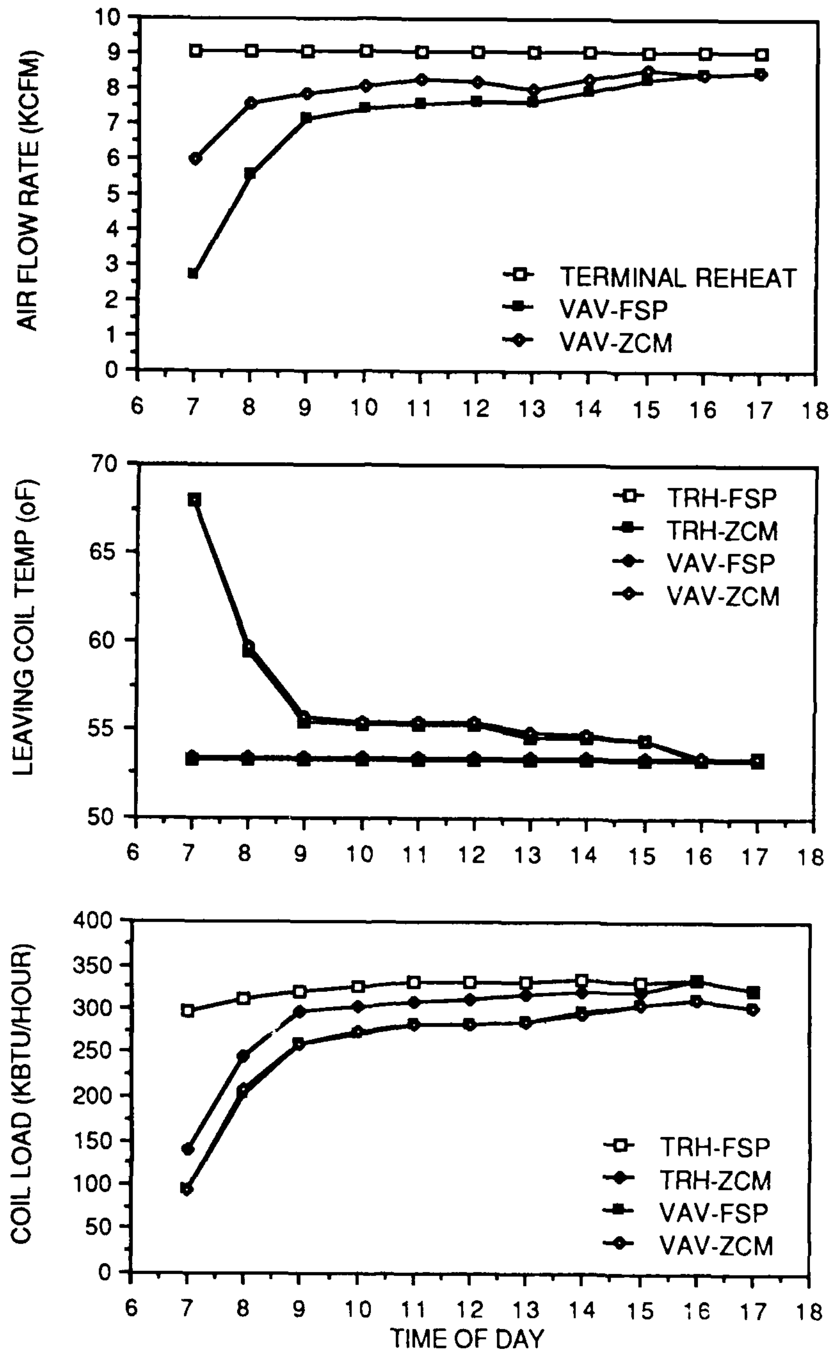

Figure 5.1-System/Control Strategy Comparison(SUMMER)

in the results. What was affected was the temperature rise of the supply and return air mixtures due to the fans. Assuming that the fans used in both systems were rated for the same design volume, the temperature rise in the VAV system was between 10% and 20% less than that of the Terminal Reheat system for the period of simulation. (This was on the order of approximately 0.5°F for the fan data input.)

This study also was able to show how each system was affected by the control strategy chosen. For the VAV system summer operation, both control schemes produced essentially the same coil load for each hour of operation. In fact, for over half the hours simulated, coil loads differed by less than 0.2%. As can be seen in Figure 5.1, the VAV system required somewhat more air volume to satisfy the loads when the zone controlled strategy was chosen. This was due to the higher coil discharge temperature allowed by this control. The control selection had a much bigger impact for the Terminal Reheat system. The reduced load during the off peak morning hours could not lead to reduced air flows. The only way to adjust to reduce coil load was to allow the leaving coil temperature to vary (zone controlled method). Use of the zone controlled method instead of the fixed set point method provided an average savings of almost 6% in the midday hours with the TRH system. (A much greater savings was realized in the start up morning hours.)

The system was allowed to shut off during the night time hours. During this time, the individual zone set point temperatures were allowed to rise to 87°F. No cooling was ever required to attain or maintain this temperature. When the system was activated in the seventh hour, the space loads were low and the leaving coil air temperature high because the zone set points were only reduced to 82°F for morning start up. Additionally, there was no latent load because occupancy was not allowed until

the eighth hour. All the remaining hours maintained set point temperatures of approximately 78°F.

5.1.2 Winter Simulations

As can be seen in Figure 5.2, the trends of the winter simulations mirrored the summer ones closely. There was a significant increase in coil load when the Terminal Reheat system was used versus the VAV system. The method of control was not important during the periods of peak loading for either system. The ability to vary the air volume with the VAV system was used to offset the penalty of fixing the leaving coil temperature. As this could not be accomplished with the TRH system, the coil load for the fixed set point method was much greater than for the zone controlled during the reduced load morning hours.

The main difference between the simulations for the two weather conditions was that a net space heating load was realized in the first morning hour of the winter. During this hour, use of the zone controlled method allowed the required coil discharge temperature to rise above the outside air temperature. Since this occurred, the dry bulb controlled economizer was able to mix outside air (45%) with return air (55%) and provide a period of "free cooling". When the fixed set point method was used, the leaving coil temperature had to be set low enough to satisfy the afternoon cooling loads. This actually produced a cooling load on the coils with both systems in the first hour, even with the economizer using 100% outside air. Also, because the supply air temperature was low, the TRH system required a significant amount of reheat for each zone. With the VAV system, the flow rate to every zone was reduced to its minimum and return air was recirculated to raise the supply air to the desired mixture temperature.

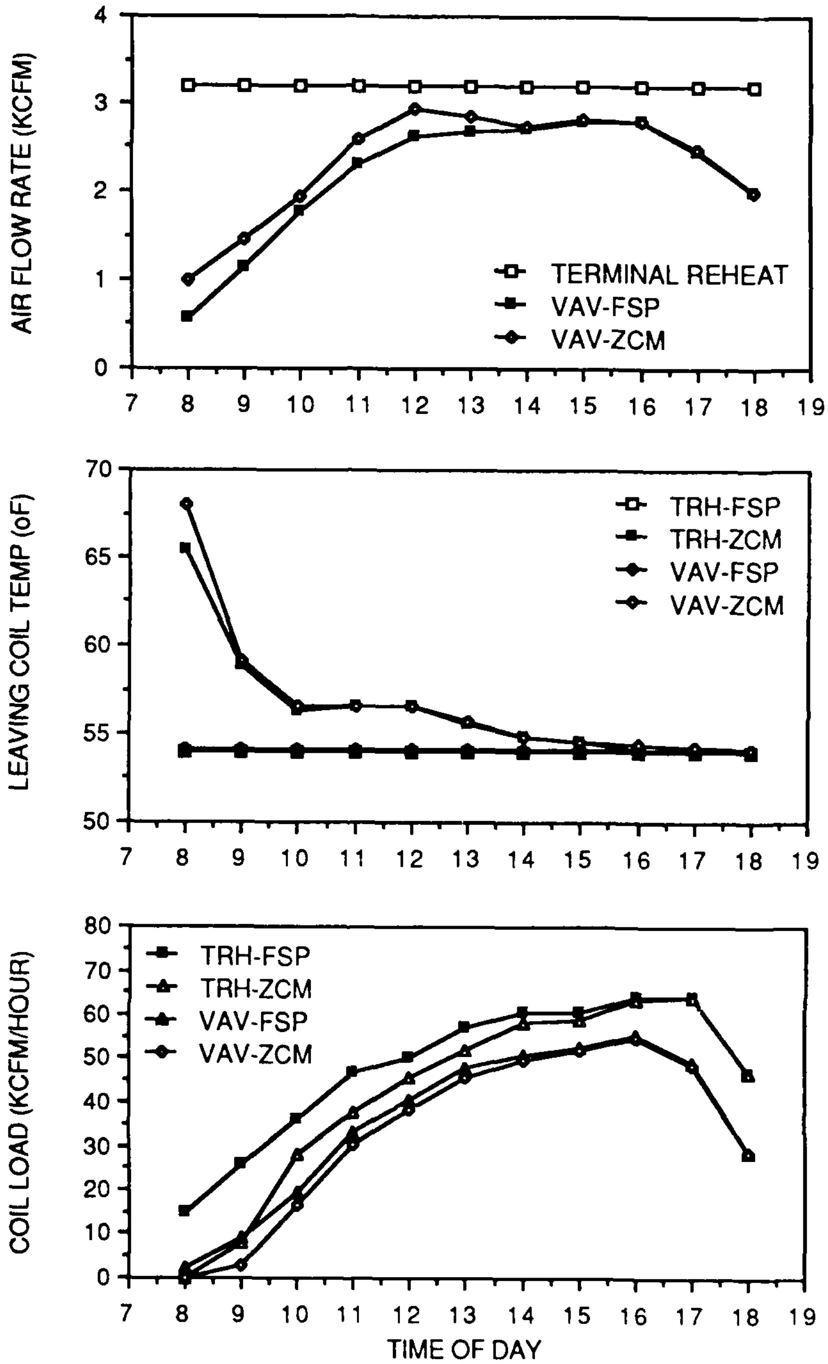

Figure 5.2-System/Control Strategy Comparison(WINTER)

5.2 CASE STUDY TWO-ECONOMIZER OPTIONS

This case study was presented to show how the economizer option chosen affects the performance of both the VAV and Terminal Reheat systems with this program. All three economizer options; no economizer, dry bulb temperature controlled and enthalpy controlled, were simulated in this study. Additionally, both systems were controlled in the simulations using both the fixed set point and zone controlled methods. All the variables listed below were used and kept constant for the simulations contained in this study.

----Duct "U" value set at 0.2 Btu/hr-ft^2.

----All other default constants unchanged.

----The minimum percentage of outside air allowed set at 10%.

----Autumn dry bulb temperatures from the Phoenix, Arizona weather used. (The wet bulb temperatures were increased to simulate a more humid climate. This was done to better show the differences between the two economizer choices under wet coil conditions.)

----Assumed maximum relative humidity off coils set at 98%.

----Plenum envelope load based on 800 Btu/hr per °F temperature difference between plenum and outside air.

----Zone sensible and latent loads, set point temperatures and lighting energy from DOE-2.1B used.

----Total design pressure drop across supply fan set at 3.5 inches of water.

----Supply fan design efficiency set at 75%.

----Supply fan motor design efficiency set at 95%.

----Total design pressure drop across return fan set at 0.5 inches of water.

----Return fan design efficiency set at 70%.

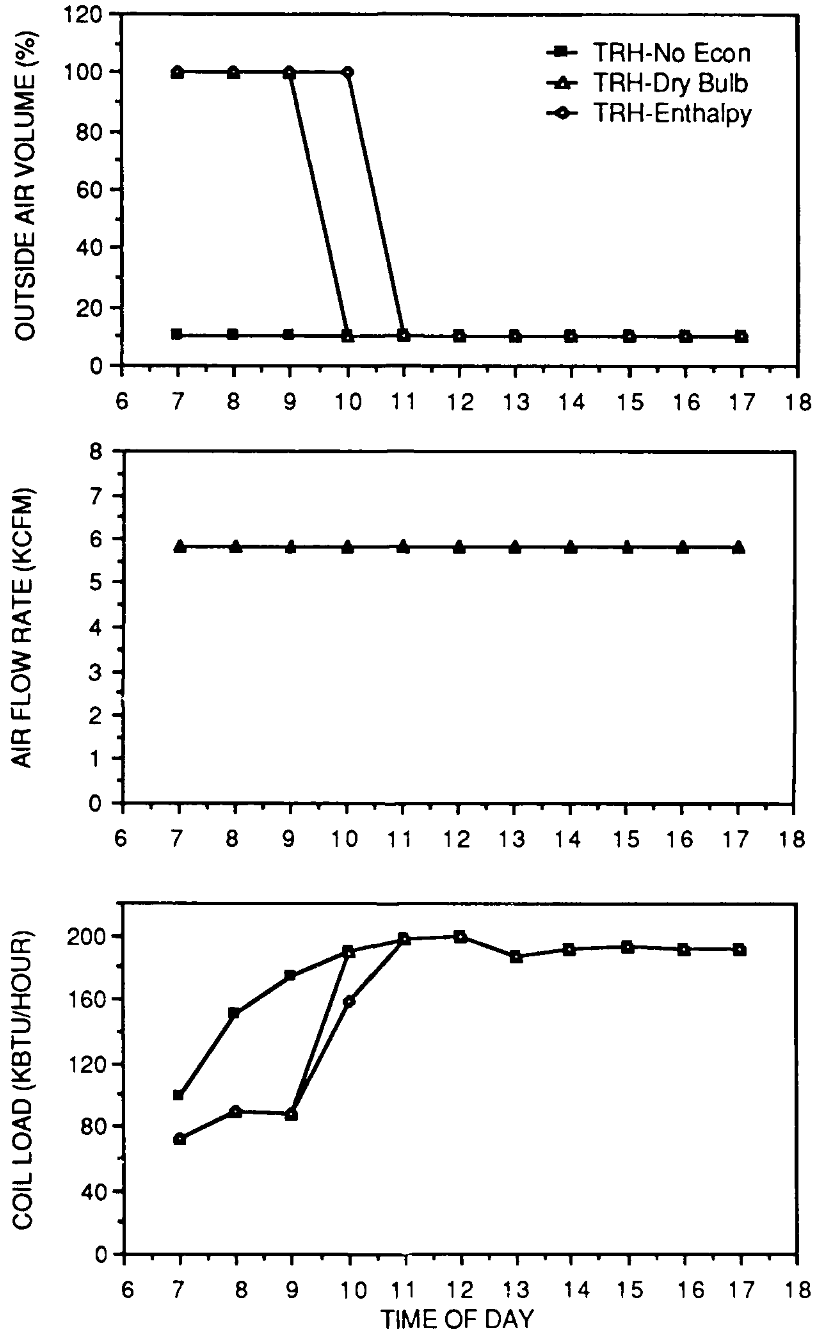

Figure 5.3 Econcomizer Performance-TRH(FSP)

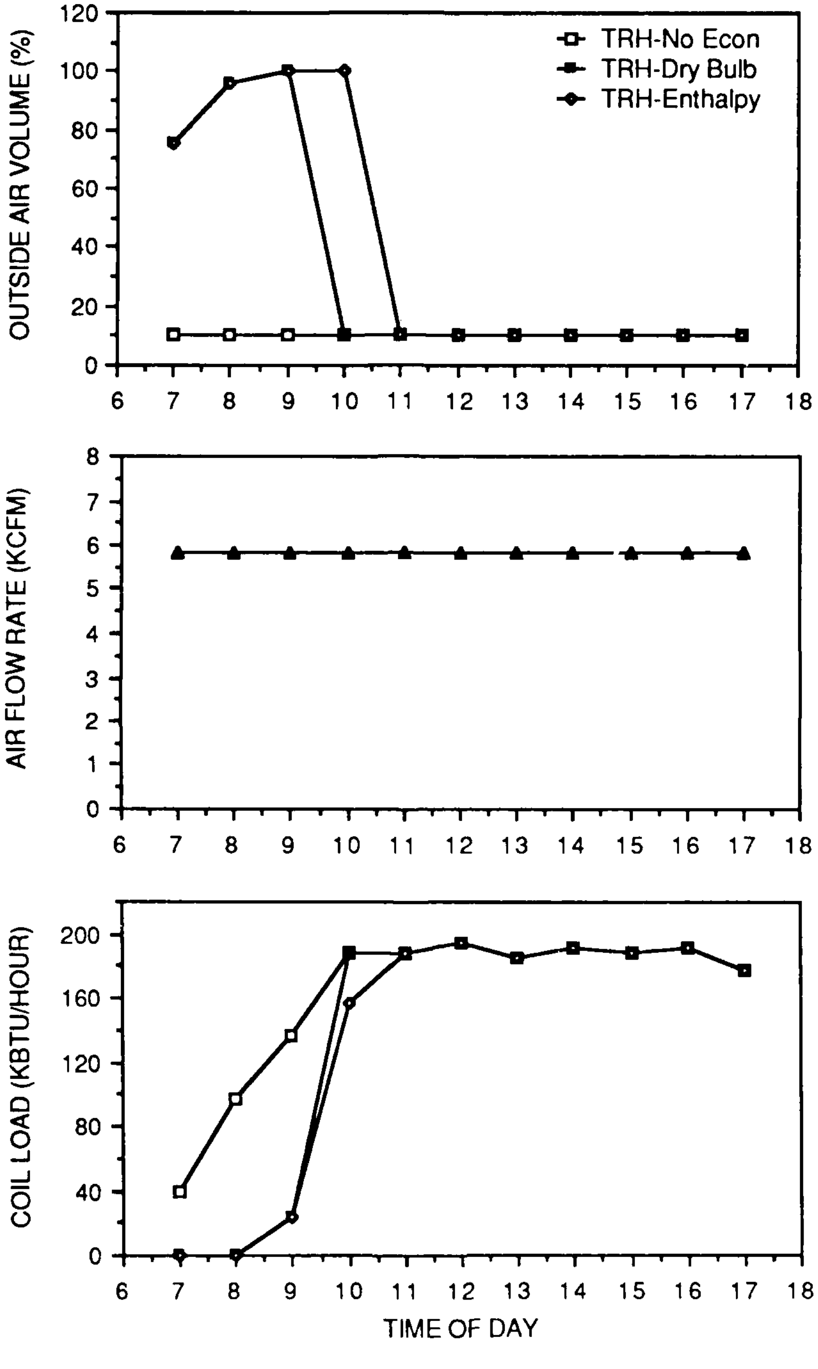

Figure 5.4 Economizer Performance-TRH(ZCM)

----Return fan motor design efficiency set at 90%.

----Constant speed fans used for Terminal Reheat simulations.

----Fans with variable speed motors used for VAV simulations. Fan performance default coefficients remained unchanged.

The individual zone air flow rates were determined using the same procedures outlined above in Case Study One. The results of this study are shown in Figures 5.3 through 5.7.

In each of the four sets of simulations conducted, use of the enthalpy controlled economizer resulted in the lowest coil load. When the VAV system were simulated as having a zone controlled leaving coil temperature, both economizer choices allowed a "free-cooling" condition to occur in the seventh and eighth hours. Additionally, as expected, when no economizer was simulated the load on the coils was at its maximum for the input loads.

This study also showed the energy savings which are lost when the dry bulb economizer is used instead of one controlled by enthalpy. In hour ten, the use of the enthalpy controlled economizer resulted in a lower coil load for both systems. The lower coil load occurred for both control strategies employed. The performance of the two economizers could be brought closer in line for a specific geographic location by selecting a higher maximum dry bulb temperature acceptable for the dry bulb controlled economizer. This could be done by changing the default value contained in the program.

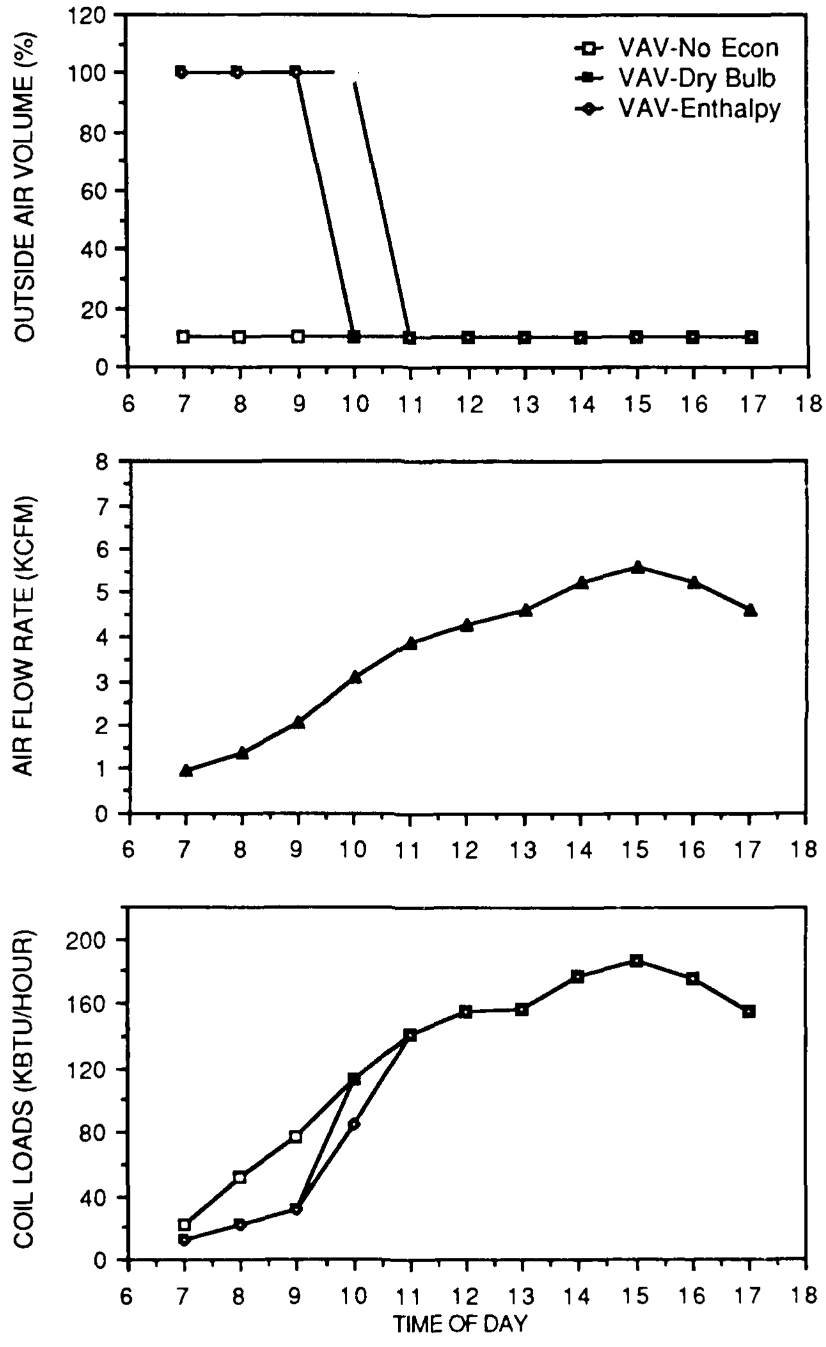

Figure 5.5 Economizer Performance-VAV(FSP)

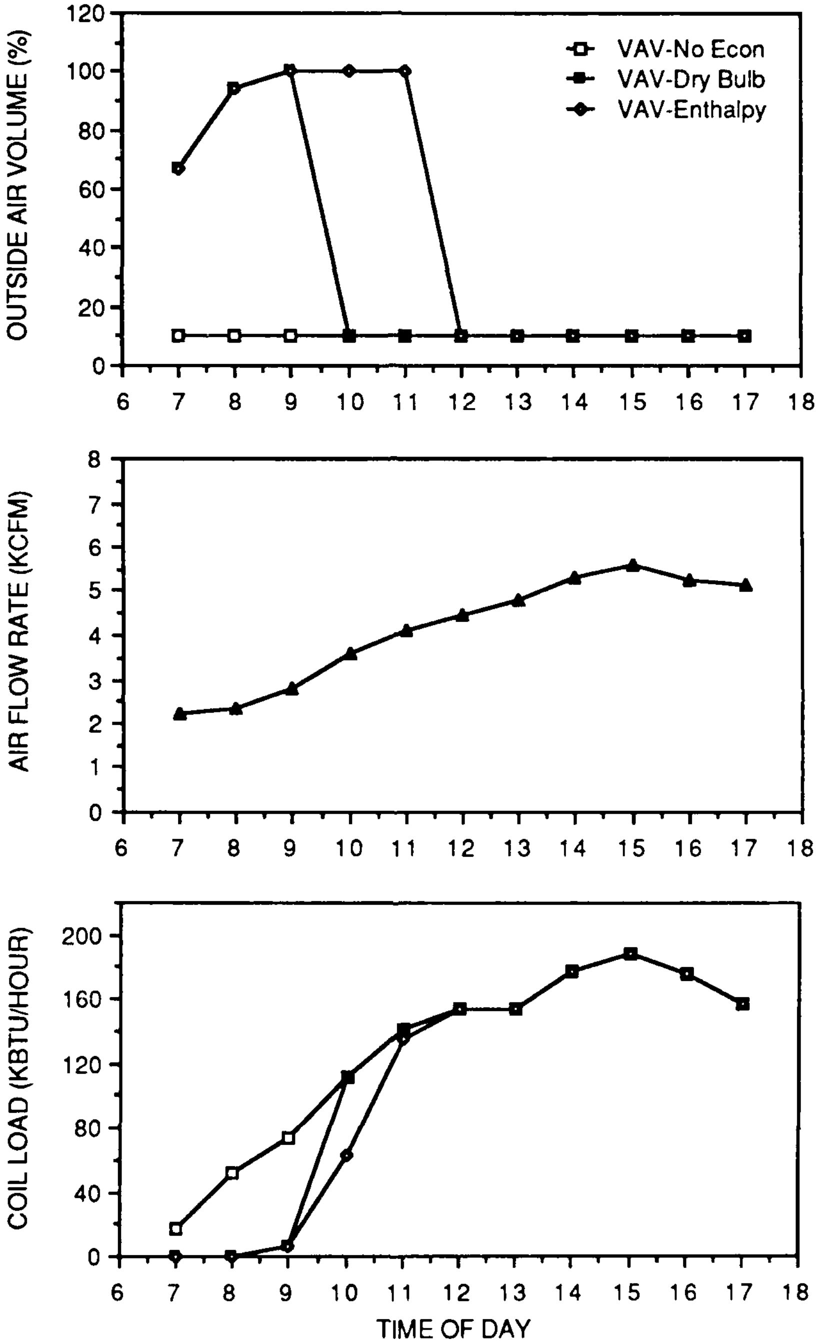

Figure 5.6 Economizer Performance-VAV(ZCM)

The results of this study were also used to compare the TRH and VAV systems under differing control strategies, as was done in Case Study One. This comparison is contained in Figure 5.7. Again, the VAV system showed a marked reduction in coil load over the TRH system for all three economizer options employed. Additionally, the relative independence of control strategy chosen for the VAV system was again evident, especially during off-peak loading.

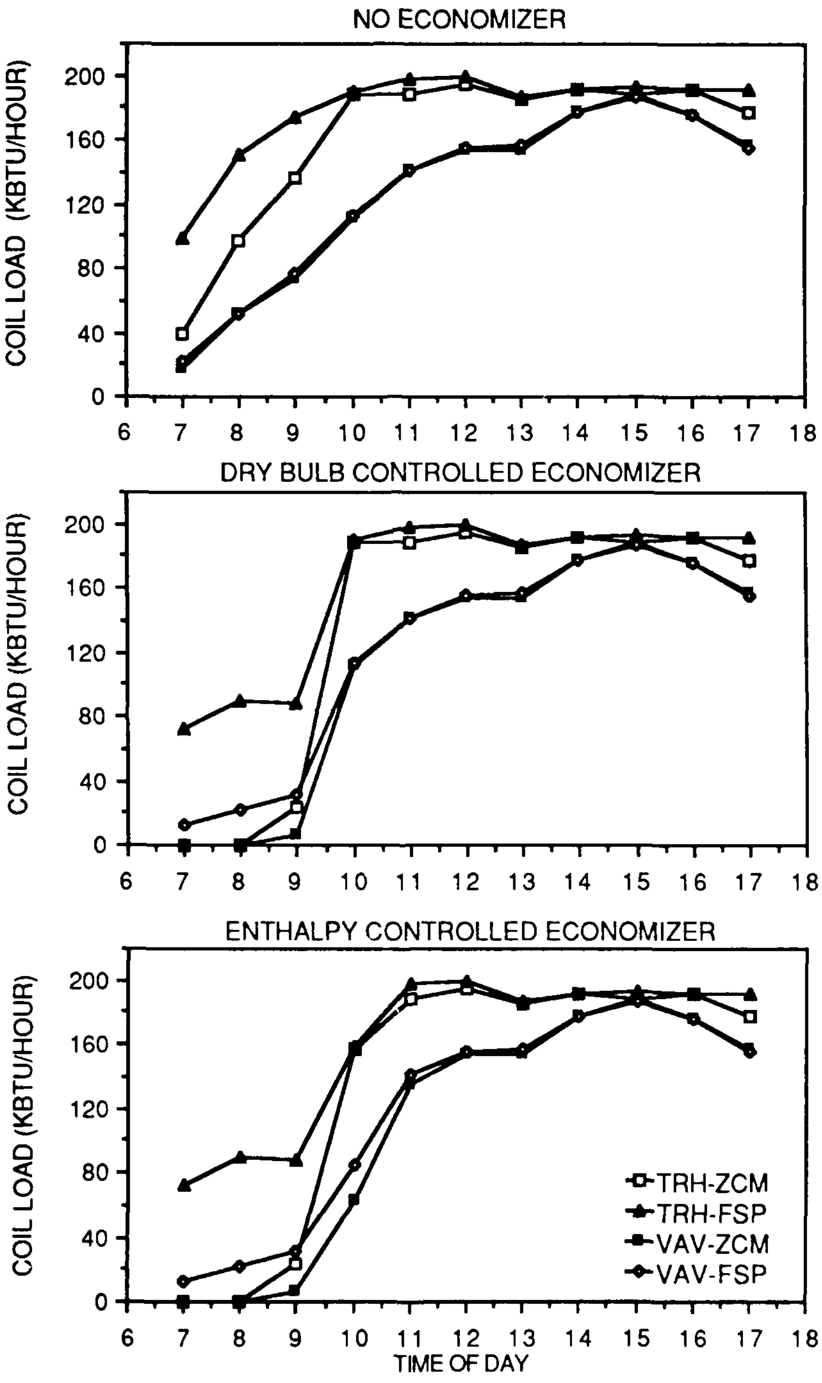

Figure 5.7 System/Control Economizer Comparison

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

For the case studies presented, the program developed by this work reacted well to changes in HVAC system and control choices. The studies showed, as expected, that the use of a VAV system instead of a Terminal Reheat system resulted in a lower load on the coils for comparable load and weather inputs. Also, because of its inability to vary the air flow to the individual zones, the Terminal Reheat system was more sensitive to the choice of control strategy employed. The second case study showed that using an economizer reduced the load on the coil by bringing the inlet conditions closer to the required outlet conditions. This study also showed that, for the input data, the enthalpy controlled economizer determined the inlet conditions equally or better than the dry bulb controlled economizer in all cases.

6.2 RECOMMENDATIONS

Many simulations were run with the program using the existing data base obtained from the DOE 2 output. All this data was for a facility in Phoenix, Arizona, a warm, dry location. It is recommended that this program be tested further using loads from other climates. Specifically, climates with a high winter heating load. Additionally, loads on the Cycling system modeled in the program were simulated by adding the loads from the individual zones and averaging the zone set point temperatures. This was accomplished in order to compare the output with the other two systems simulated. The resulting output seemed to show the correct load trends but, since the manner for input was

questionable, the results were not included in the case studies as comparable results to the other two systems. Therefore, it is suggested that load data for a single zone facility be used to further test the model.

It is believed that the program developed by this work is flexible and provides the user with many system and control choices by which to simulate HVAC operations. There are, though, many other systems and control choices which are needed in certain instances. It is recommended that this program be expanded to include other system choices. Single duct systems should be able to use many of the same subroutines developed here. Multiduct systems may need additional subroutines to handle the supply air delivery. It is also recommended that variations to the systems already included in the program be looked at for possible inclusion. Included here are Terminal Reheat and VAV systems with baseboard heaters for exterior zones and no induction for the VAV system.

One of the limitations to this program mentioned earlier was the fact that it was developed under the assumptions of constant standard barometric pressure and at sea level. The equations for specific volume contain the pressure implicitly in the 0.0252112 constant term. The specific enthalpy equations were all developed using data which was developed for the standard conditions. The equation for the saturated humidity ratio does carry an explicit pressure term, but it was considered a constant for this work. It is suggested that these variables be modified to allow for a variable atmospheric pressure. The pressure could be included in the default constants section of the main program and passed to the applicable subroutines in common block AAAAA; which is included in all subroutines. Then, the user would be able to vary the pressure, if needed, without having to input it every time when standard pressure conditions exist. Additionally,

correction factors for altitude are available which would allow for the altitude to be an input.[7] The factor, passed again in common block AAAAA, could be included in the applicable equations with no change in programming logic or execution.

Modifications to the program in the area of duct geometry should be included to allow for the simulation of round, square, rectangular or flat oval duct. If this is accomplished, the changes should be made to the area calculation equations in the main program and the duct heat loss equations of subroutines TDUCT and QDUCT.

Finally, this program could be combined with other programs. It could be mated with the output from a loads program which would set up the permanent files and greatly reduce the amount of initial input required to execute the program. Furthermore, the program's output files could be reformatted and become the input to subsequent component energy simulations and economic programs. This would provide an overall energy characterization tool for use in HVAC systems design. The development of such a tool would prove invaluable to the HVAC engineer in optimal systems decisions. It would be inexpensive to use and readily available for the average practicing HVAC engineer.

APPENDIX A

SIMULATION INPUT/OUTPUT FILES

INPUT DATA
============

```
(1) SYSTEM USED............................ VARIABLE AIR VOLUME WITH
                                            INDUCTION REHEATERS
(2) CONTROL METHOD USED.................... ZONE CONTROLLED
(3) ECONOMIZER METHOD...................... OUTSIDE AIR CONTROLLED
    (3a) Minimum percentage................ 10.0%
         of outside air allowed
(4) WEATHER DATA FILENAME ................. JULW
(5) ZONE UNIQUE DATA FILENAME.............. JULVAV5
    (5a) Maximum zone primary air.......... JULCFMMX
         volume rate & maximum induction
         air volume rate data filename
(6) SUPPLY FAN DATA
    (6a) Design total pressure drop....... 3.50(inches of water)
    (6b) Fan design efficiency ........... 75.0%
    (6c) Motor design efficiency.......... 95.0%
    (6d) Fan air volume control method ... VARIABLE SPEED MOTOR
(7) RETURN FAN DATA
    (7a) Design total pressure drop.......  .50(inches of water)
    (7b) Fan design efficiency............ 70.0%
    (7c) Motor design efficiency ......... 90.0%
    (7d) Fan air volume control method ... VARIABLE SPEED MOTOR
(8) NUMBER OF CHANGES FOR VALUES OF THE... 0
    DEFAULT CONSTANTS
```

SYSTEM DATA

HOUR	TEMPERATURE LEAVING COOLING COIL(oF)	HUMIDITY RATIO LEAVING CCOIL	COOLING COIL LOAD (BTU/HR)	PREHEATER LOAD (BTU/HR)	PERCENT OUTSIDE AIR USED (%/100)
1		**** PRIMARY SYSTEM OFF ****			
2		**** PRIMARY SYSTEM OFF ****			
3		**** PRIMARY SYSTEM OFF ****			
4		**** PRIMARY SYSTEM OFF ****			
5		**** PRIMARY SYSTEM OFF ****			
6		**** PRIMARY SYSTEM OFF ****			
7	68.0	.01383	92893.6	.0	.10
8	59.7	.01075	208402.5	.0	.10
9	55.7	.00927	259877.2	.0	.10
10	55.4	.00918	273986.7	.0	.10
11	55.4	.00919	283580.9	.0	.10
12	55.4	.00918	283859.8	.0	.10
13	54.8	.00897	284868.6	.0	.10
14	54.7	.00894	295306.5	.0	.10
15	54.4	.00886	304937.0	.0	.10
16	53.4	.00852	311709.7	.0	.10
17	53.5	.00856	303963.5	.0	.10
18		**** PRIMARY SYSTEM OFF ****			
19		**** PRIMARY SYSTEM OFF ****			
20		**** PRIMARY SYSTEM OFF ****			
21		**** PRIMARY SYSTEM OFF ****			
22		**** PRIMARY SYSTEM OFF ****			
23		**** PRIMARY SYSTEM OFF ****			
24		**** PRIMARY SYSTEM OFF ****			

ZONE DATA

	ZONE 1			ZONE 2			ZONE 3		
	PRIMARY	INDCTN	REHEAT	PRIMARY	INDCTN	REHEAT	PRIMARY	INDCTN	REHEAT
HOUR	CFM	CFM	BTU/HR	CFM	CFM	BTU/HR	CFM	CFM	BTU/HR
1	.0	.0	.0	.0	.0	.0	.0	.0	.0
2	.0	.0	.0	.0	.0	.0	.0	.0	.0
3	.0	.0	.0	.0	.0	.0	.0	.0	.0
4	.0	.0	.0	.0	.0	.0	.0	.0	.0
5	.0	.0	.0	.0	.0	.0	.0	.0	.0
6	.0	.0	.0	.0	.0	.0	.0	.0	.0
7	1258.4	.0	.0	1122.5	.0	.0	1161.1	.0	.0
8	1172.8	.0	.0	1473.9	.0	.0	1523.4	.0	.0
9	1017.8	.0	.0	1812.8	.0	.0	1640.1	.0	.0
10	1032.7	.0	.0	1850.0	.0	.0	1712.5	.0	.0
11	1125.4	.0	.0	1850.0	.0	.0	1750.2	.0	.0
12	1165.8	.0	.0	1850.0	.0	.0	1788.8	.0	.0
13	1169.4	.0	.0	1850.0	.0	.0	1751.4	.0	.0
14	1335.4	.0	.0	1850.0	.0	.0	1822.5	.0	.0
15	1611.1	.0	.0	1850.0	.0	.0	1850.0	.0	.0
16	1700.0	.0	.0	1777.1	.0	.0	1828.4	.0	.0
17	1700.0	.0	.0	1850.0	.0	.0	1850.0	.0	.0
18	.0	.0	.0	.0	.0	.0	.0	.0	.0
19	.0	.0	.0	.0	.0	.0	.0	.0	.0
20	.0	.0	.0	.0	.0	.0	.0	.0	.0
21	.0	.0	.0	.0	.0	.0	.0	.0	.0
22	.0	.0	.0	.0	.0	.0	.0	.0	.0
23	.0	.0	.0	.0	.0	.0	.0	.0	.0
24	.0	.0	.0	.0	.0	.0	.0	.0	.0

	ZONE 4			ZONE 5		
	PRIMARY	INDCTN	REHEAT	PRIMARY	INDCTN	REHEAT
HOUR	CFM	CFM	BTU/HR	CFM	CFM	BTU/HR
1	.0	.0	.0	.0	.0	.0
2	.0	.0	.0	.0	.0	.0
3	.0	.0	.0	.0	.0	.0
4	.0	.0	.0	.0	.0	.0
5	.0	.0	.0	.0	.0	.0
6	.0	.0	.0	.0	.0	.0
7	1469.4	.0	.0	985.8	.0	.0
8	1704.3	.0	.0	1675.0	.0	.0
9	1683.5	.0	.0	1675.0	.0	.0
10	1[illegible]99.6	.0	.0	1675.0	.0	.0
11	1858.4	.0	.0	1675.0	.0	.0
12	2000.0	.0	.0	1427.3	.0	.0
13	2000.0	.0	.0	1250.4	.0	.0
14	2000.0	.0	.0	1266.7	.0	.0
15	2000.0	.0	.0	1249.9	.0	.0
16	1942.4	.0	.0	1192.0	.0	.0
17	19[illegible]6.2	.0	.0	1183.3	.0	.0
18	.0	.0	.0	.0	.0	.0
19	.0	.0	.0	.0	.0	.0
20	.0	.0	.0	.0	.0	.0
21	.0	.0	.0	.0	.0	.0
22	.0	.0	.0	.0	.0	.0
23	.0	.0	.0	.0	.0	.0
24	.0	.0	.0	.0	.0	.0

WEATHER FILE DATA

HOUR	OUTSIDE DRY BULB TEMPERATURE (oF)	OUTSIDE WET BULB TEMPERATURE (oF)	PLENUM ENVELOPE LOAD (BTU/HR)	MAX. REL. HUMIDITY EXITING COILS (%)
1	91.00	70.00	8000.0	98.00
2	90.00	70.00	7200.0	98.00
3	88.00	70.00	5600.0	98.00
4	87.00	69.00	4800.0	98.00
5	85.00	69.00	3200.0	98.00
6	87.00	69.0	4800.0	98.00
7	88.00	70.00	5600.0	98.00
8	90.00	70.00	7200.0	98.00
9	94.00	71.00	10400.0	98.00
10	97.00	72.00	12800.0	98.00
11	101.00	73.00	16000.0	98.00
12	103.00	73.00	17600.0	98.00
13	105.00	73.00	19200.0	98.00
14	107.00	73.00	20800.0	98.00
15	108.00	72.00	21600.0	98.00
16	108.00	72.00	21600.0	98.00
17	109.00	71.00	22400.0	98.00
18	108.00	71.00	21600.0	98.00
19	106.00	71.00	20000.0	98.00
20	105.00	71.00	19200.0	98.00
21	103.00	70.00	17600.0	98.00
22	101.00	70.00	16000.0	98.00
23	99.00	70.00	14400.0	98.00
24	97.00	70.00	12800.0	98.00

INPUT DATA FOR ZONE NAMED WEST (ZONE 1)

ZONE AREA	1050.00000 SQ.FT.
TRUNK DUCT LENGTH TO BRANCH	7.50000 FT.
BRANCH DUCT LENGTH	25.00000 FT.
CEILING "U" VALUE	.30000 BTU/HR-SQ.FT.-oF

HOUR	SENSIBLE LOAD (BTU/HR)	LATENT LOAD (BTU/HR)	MINIMUM AIR FLOW RATE (CFM)	SET POINT TEMPERATURE (oF)	TOTAL LIGHTING ENERGY* (BTU/HR)	LIGHTING ENERGY TO PLENUM* (BTU/HR)
1	.0	.0	.0	87.0	892.5	535.5
2	.0	.0	.0	87.0	892.5	535.5
3	.0	.0	.0	87.0	892.5	535.5
4	.0	.0	.0	87.0	892.5	535.5
5	.0	.0	.0	87.0	892.5	535.5
6	.0	.0	.0	87.0	892.5	535.5
7	12212.0	600.0	60.0	79.1	892.5	535.5
8	19156.0	1200.0	60.0	77.7	8925.0	5355.0
9	20754.0	1200.0	60.0	77.8	8925.0	5355.0
10	21422.0	1200.0	60.0	77.9	8925.0	5355.0
11	23418.0	1200.0	60.0	78.0	8925.0	5355.0
12	24323.0	1200.0	60.0	78.0	8925.0	5355.0
13	25322.0	1200.0	60.0	78.1	8925.0	5355.0
14	29357.0	1200.0	60.0	78.3	8925.0	5355.0
15	36551.0	1200.0	60.0	78.7	8925.0	5355.0
16	42837.0	1200.0	60.0	79.0	8925.0	5355.0
17	44780.0	600.0	60.0	80.2	8925.0	5355.0
18	.0	.0	.0	87.0	8925.0	5355.0
19	.0	.0	.0	87.0	8925.0	5355.0
20	.0	.0	.0	87.0	892.5	535.5
21	.0	.0	.0	87.0	892.5	535.5
22	.0	.0	.0	87.0	892.5	535.5
23	.0	.0	.0	87.0	892.5	535.5
24	.0	.0	.0	87.0	892.5	535.5

*NOTE: THE ENERGY ENTERING THE ZONE IS INCLUDED IN THE SENSIBLE LOAD

MAXIMUM PRIMARY AIR FLOW RATE (CFM)	MAXIMUM INDUCTION AIR FLOW RATE (CFM)
1700.00	1375.00

INPUT DATA FOR ZONE NAMED CENTRAL (ZONE 2)

ZONE AREA	4900.00000	SQ.FT.
TRUNK DUCT LENGTH TO BRANCH	50.00000	FT.
BRANCH DUCT LENGTH	20.00000	FT.
CEILING "U" VALUE	.30000	BTU/HR-SQ.FT.-oF

HOUR	SENSIBLE LOAD (BTU/HR)	LATENT LOAD (BTU/HR)	MINIMUM AIR FLOW RATE (CFM)	SET POINT TEMPERATURE (oF)	TOTAL LIGHTING ENERGY* (BTU/HR)	LIGHTING ENERGY TO PLENUM* (BTU/HR)
1	.0	.0	.0	87.0	4165.0	2499.0
2	.0	.0	.0	87.0	4165.0	2499.0
3	.0	.0	.0	87.0	4165.0	2499.0
4	.0	.0	.0	87.0	4165.0	2499.0
5	.0	.0	.0	87.0	4165.0	2499.0
6	.0	.0	.0	87.0	4165.0	2499.0
7	13939.0	2800.0	280.0	82.0	4165.0	2499.0
8	25567.0	5600.0	280.0	78.8	41650.0	24990.0
9	39126.0	5600.0	280.0	78.9	41650.0	24990.0
10	40703.0	5600.0	280.0	78.9	41650.0	24990.0
11	40790.0	5600.0	280.0	79.0	41650.0	24990.0
12	42592.0	5600.0	280.0	79.2	41650.0	24990.0
13	42907.0	5600.0	280.0	79.3	41650.0	24990.0
14	43248.0	5600.0	280.0	79.5	41650.0	24990.0
15	43517.0	5600.0	280.0	79.6	41650.0	24990.0
16	43463.0	5600.0	280.0	79.6	41650.0	24990.0
17	44320.0	2800.0	280.0	79.0	41650.0	24990.0
18	.0	.0	.0	87.0	41650.0	24990.0
19	.0	.0	.0	87.0	41650.0	24990.0
20	.0	.0	.0	87.0	4165.0	2499.0
21	.0	.0	.0	87.0	4165.0	2499.0
22	.0	.0	.0	87.0	4165.0	2499.0
23	.0	.0	.0	87.0	4165.0	2499.0
24	.0	.0	.0	87.0	4165.0	2499.0

*NOTE: THE ENERGY ENTERING THE ZONE IS INCLUDED IN THE SENSIBLE LOAD

MAXIMUM PRIMARY AIR FLOW RATE (CFM)	MAXIMUM INDUCTION AIR FLOW RATE (CFM)
1850.00	1390.00

INPUT DATA FOR ZONE NAMED NORTH (ZONE 3)

ZONE AREA	1500.00000	SQ.FT.
TRUNK DUCT LENGTH TO BRANCH	50.00000	FT.
BRANCH DUCT LENGTH	70.00000	FT.
CEILING "U" VALUE	.30000	BTU/HR-SQ.FT.-oF

HOUR	SENSIBLE LOAD (BTU/HR)	LATENT LOAD (BTU/HR)	MINIMUM AIR FLOW RATE (CFM)	SET POINT TEMPERATURE (oF)	TOTAL LIGHTING ENERGY* (BTU/HR)	LIGHTING ENERGY TO PLENUM* (BTU/HR)
1	.0	.0	.0	87.0	1275.0	765.0
2	.0	.0	.0	87.0	1275.0	765.0
3	.0	.0	.0	87.0	1275.0	765.0
4	.0	.0	.0	87.0	1275.0	765.0
5	.0	.0	.0	87.0	1275.0	765.0
6	.0	.0	.0	87.0	1275.0	765.0
7	13472.0	857.0	85.0	81.8	1275.0	765.0
8	24272.0	1715.0	85.0	78.2	12750.0	7650.0
9	33008.0	1715.0	85.0	78.4	12750.0	7650.0
10	35144.0	1715.0	85.0	78.5	12750.0	7650.0
11	35977.0	1715.0	85.0	78.6	12750.0	7650.0
12	36860.0	1715.0	85.0	78.6	12750.0	7650.0
13	37358.0	1715.0	85.0	78.7	12750.0	7650.0
14	39226.0	1715.0	85.0	78.8	12750.0	7650.0
15	41188.0	1715.0	85.0	78.9	12750.0	7650.0
16	41792.0	1715.0	85.0	78.9	12750.0	7650.0
17	42091.0	857.0	85.0	78.9	12750.0	7650.0
18	.0	.0	.0	87.0	12750.0	7650.0
19	.0	.0	.0	87.0	12750.0	7650.0
20	.0	.0	.0	87.0	1275.0	765.0
21	.0	.0	.0	87.0	1275.0	765.0
22	.0	.0	.0	87.0	1275.0	765.0
23	.0	.0	.0	87.0	1275.0	765.0
24	.0	.0	.0	87.0	1275.0	765.0

*NOTE. THE ENERGY ENTERING THE ZONE IS INCLUDED IN THE SENSIBLE LOAD.

MAXIMUM PRIMARY AIR FLOW RATE (CFM)	MAXIMUM INDUCTION AIR FLOW RATE (CFM)
1850.00	1390.00

INPUT DATA FOR ZONE NAMED SOUTH (ZONE 4)

ZONE AREA	1500.00000 SQ.FT.
TRUNK DUCT LENGTH TO BRANCH	50.00000 FT.
BRANCH DUCT LENGTH	70.00000 FT.
CEILING "U" VALUE	30000 BTU/HR-SQ.FT.-oF

HOUR	SENSIBLE LOAD (BTU/HR)	LATENT LOAD (BTU/HR)	MINIMUM AIR FLOW RATE (CFM)	SET POINT TEMPERATURE (oF)	TOTAL LIGHTING ENERGY* (BTU/HR)	LIGHTING ENERGY TO PLENUM* (BTU/HR)
1	.0	.0	0	87.0	1275.0	765.0
2	.0	.0	.0	87.0	1275.0	765.0
3	.0	.0	.0	87.0	1275.0	765.0
4	.0	.0	.0	87.0	1275.0	765.0
5	.0	.0	.0	87.0	1275.0	765.0
6	.0	.0	.0	87.0	1275.0	765.0
7	15078.0	857.0	85.0	80.3	1275.0	765.0
8	26954.0	1715.0	85.0	78.0	12750.0	7650.0
9	33519.0	1715.0	85.0	78.2	12750.0	7650.0
10	36777.0	1715.0	85.0	78.4	12750.0	7650.0
11	38250.0	1715.0	85.0	78.6	12750.0	7650.0
12	42410.0	1715.0	85.0	78.6	12750.0	7650.0
13	44629.0	1715.0	85.0	78.7	12750.0	7650.0
14	44938.0	1715.0	85.0	78.8	12750.0	7650.0
15	45359.0	1715.0	85.0	78.8	12750.0	7650.0
16	44069.0	1715.0	85.0	78.7	12750.0	7650.0
17	43009.0	857.0	85.0	78.6	12750.0	7650.0
18	.0	0	0	87.0	12750.0	7650.0
19	0	.0	0	87.0	12750.0	7650.0
20	.0	.0	.0	87.0	1275.0	765.0
21	0	.0	0	87.0	1275.0	765.0
22	.0	.0	.0	87.0	1275.0	765.0
23	.0	.0	.0	87.0	1275.0	765.0
24	.0	.0	.0	87.0	1275.0	765.0

*NOTE: THE ENERGY ENTERING THE ZONE IS INCLUDED IN THE SENSIBLE LOAD

MAXIMUM PRIMARY AIR FLOW RATE (CFM)	MAXIMUM INDUCTION AIR FLOW RATE (CFM)
2000.00	1500.00

INPUT DATA FOR ZONE NAMED EAST (ZONE 5)

ZONE AREA	1050 00000 SQ FT.
TRUNK DUCT LENGTH TO BRANCH	92 50000 FT.
BRANCH DUCT LENGTH	25 00000 FT.
CEILING "U" VALUE	.30000 BTU/HR-SQ.FT.-oF

HOUR	SENSIBLE LOAD (BTU/HR)	LATENT LOAD (BTU/HR)	MINIMUM AIR FLOW RATE (CFM)	SET POINT TEMPERATURE (oF)	TOTAL LIGHTING ENERGY* (BTU/HR)	LIGHTING ENERGY TO PLENUM* (BTU/HR)
====	========	========	========	===========	========	=========
1	0	.0	.0	87.0	892.5	535.5
2	.0	.0	.0	87 0	892 5	535.5
3	.0	0	0	87.0	892 5	535.5
4	.0	.0	.0	87 0	892.5	535 5
5	.0	.0	.0	87.0	892 5	535.5
6	.0	.0	.0	87.0	892.5	535 5
7	11442.0	600 0	60.0	81.7	892.5	535.5
8	29218.0	1200.0	60.0	78 8	8925.0	5355 0
9	39028 0	1200.0	60 0	80 3	8925.0	5355.0
10	37499 0	1200.0	60.0	79 2	8925 0	5355.0
11	36795.0	1200.0	60 0	78.9	8925.0	5355.0
12	29380.0	1200.0	60.0	78.5	8925.0	5355.0
13	26099.0	1200 0	60 0	78 3	8925 0	5355.0
14	26640.0	1200.0	60 0	78 4	8925.0	5355.0
15	26507 0	1200 0	60.0	78.4	8925 0	5355.0
16	26431.0	1200 0	60.0	78 4	8925.0	5355.0
17	25959 0	600 0	60 0	78.3	8925.0	5355.0
18	.0	.0	.0	87.0	8925 0	5355.0
19	0	.0	.0	87 0	8925 0	5355.0
20	.0	.0	.0	87 0	892.5	535.5
21	.0	0	.0	87.0	892.5	535.5
22	.0	.0	.0	87.0	892.5	535.5
23	0	.0	.0	87.0	892.5	535.5
24	.0	.0	.0	87.0	892.5	535.5

*NOTE. THE ENERGY ENTERING THE ZONE IS INCLUDED IN THE SENSIBLE LOAD

MAXIMUM PRIMARY AIR FLOW RATE (CFM)	MAXIMUM INDUCTION AIR FLOW RATE (CFM)
===============	=================
1675 00	1250.00

APPENDIX B

NOMENCLATURE OF PROGRAM VARIABLES

This appendix is provided to give a brief description of the variables used in the program source code contained in Appendix D.

VARIABLE NAMES	DESCRIPTION	UNITS
ACFM(I)	Design trunk duct air volume rate	ft^3/min
ACFMZ(I)	Design branch duct air volume rate	ft^3/min
AD(I)	Design trunk duct area	ft^2
ADZ(I)	Design branch duct area	ft^2
AZ(I)	Zone area	ft^2
AMXECON	Maximum allowable outside air bulb temperature for economizer operation	°F
AMXTLCC	Maximum allowable leaving coil temperature	°F
CFM(I,J)	Trunk duct air volume rate (at zone branch off)	ft^3/min
CFMZ(I,J)	Branch duct(zone) air volume rate	ft^3/min
CFMZI(I,J)	Zone induction air volume rate	ft^3/min
CFMZIM(I)	Maximum zone induction air volume rate	ft^3/min
CFMZMN(I,J)	Minimum zone air volume rate	ft^3/min
CFMZMX(I)	Maximum zone air volume rate	ft^3/min
CPA	Specific heat of dry air	Btu/lbm-°F
CPL	Specific heat of liquid water	Btu/lbm-°F
CPV	Specific heat of vapor	Btu/lbm-°F
CPMLCC	Specific heat of moist air mixture leaving the coils	Btu/lbm-°F
CPMMIX	Specific heat of moist air mixture entering the coils	Btu/lbm-°F
CPMR	Specific heat of returning moist air mixture	Btu/lbm-°F
CPV	Specific heat of vapor	Btu/lbm-°F
DTD(I)	Temperature change in segment of trunk duct	°F
DTDT(I)	Total temperature change in trunk duct	°F
DTDZ(I)	Temperature change in branch duct	°F
DTRF	Temperature rise due to return fan	°F
DTRH(I)	Temperature change required for reheat	°F
DTSF	Temperature rise due to supply fan	°F
FANTYP	Type of fan/control method used	Characters
FCHOOZ	Editing option for weather file	Characte[illegible]

VARIABLE NAMES	DESCRIPTION	UNITS
FCHUZM	Editing option for maximum primary and secondary air volume rates file (for use with the VAV system)	Character
FCHUZS	Editing option for outside air controlled leaving coil temperature schedule file	Character
FCHUZZ	Editing option for zone unique data file	Character
FLUXW	Plenum wall heat flux	Btu/hr-°F
FNAME	File name for weather data	Characters
FRDL	Fraction of total air volume lost due to duct leakage	%/100
FRHRA	Assumed system running time per hour	
FRHR(J)	Actual system running time per hour	
FRQLGT	Fraction of lighting energy which enters the plenum	%/100
FZNAME	File name for zone unique data file	
HG	Enthalpy of saturated vapor	Btu/lbm-°F
HGLCC	Enthalpy of saturated vapor leaving cooling coil	Btu/lbm-°F
HLCC	Enthalpy of air mixture leaving cooling coil	Btu/lbm-°F
HRA	Enthalpy of return air mixture	Btu/lbm-°F
ICNTRL	Control method choice	Integer
ICT	Fan part load characteristic choice	Character
IFLAG1	Determines if a return temperature has been calculated.	Integer
IFLAG2	Determines if a final leaving coil temperature has been calculated.	Integer
IFLAG3	Determines if an interim leaving coil temperature has been calculated	Integer
IFLAG4	Determines if all outside temperatures encountered in the simulation have been entered in the outside air control schedule.	Integer
IFLAG5	Determines if zone CFMs have been calculated for a particular interim leaving coil temperature	Integer
IFLAG6	Determines if zone CFM iterations have been accomplished within the CFMREQD subroutine for the VAV system option.	Integer
IFLAG7	Sets the controlling zone	Integer

VARIABLE NAMES	DESCRIPTION	UNITS
IFLAG8(I)	Determines if zone CFMs have been set to their minimum value with the VAV system option	Integer
IMOA	Economizer method choice	Integer
ISFAN	Fan choice	Integer
ISYSTM	System choice	Integer
IWCHK	Determines if the coil is dry	Integer
JX	Hour designator in subroutines	Integer
L(I)	Distance from system to zone branch along trunk duct	ft
LZ(I)	Length of branch duct	ft
MAXCFM	File name for maximum primary and secondary air volume rate file (for use with VAV system)	Characters
MIN	Controlling zone indicator	Integer
MN	Controlling zone indicator (for use with VAV system)	Integer
OUTFILE	File name for saving output	Characters
PI	Pi-computed as 4*Arctan(1.0)	Radians
PTOA(J)	Fraction of outside air volume used	%/100
PTOAM	Minimum fraction of outside air volume allowable	%/100
QCCL(J)	Cooling coil total load	Btu/hr
QDUCT	Heat loss/gain in duct system	Btu/hr
QLGZ(I,J)	Zone lighting energy	Btu/hr-ft^2
QLZ(I,J)	Zone latent load	Btu/hr
QPH(J)	Preheat coil load	Btu/hr
QPLW(J)	Plenum wall load	Btu-hr
QRHZ(I,J)	Zone reheater load	Btu/hr
QSZ(I,J)	Zone sensible load	Btu/hr
RFANn	Return fan design efficiency	%/100
RFHP	Return fan design horsepower	hp
RFPLD(K)	Return fan part load characteristic coefficient change choice	Character
RH(J)	Assumed relative humidity leaving cooling coil	
RMOTn	Return fan motor design efficiency	%/100
SCHDLE	File name for outside air control method schedule	Characters
SFANn	Supply fan design efficiency	%/100
SFHP	Supply fan design horsepower	hp
SFPLD(K)	Supply fan part load characteristic coefficient change choice	Character
SMOTn	Supply fan motor design efficiency	%/100
SPVI(I)	Specific volume of induction air	ft^3/lbm

VARIABLE NAMES	DESCRIPTION	UNITS
SPVS(I)	Specific volume of zone supply air	ft^3/lbm
SPVSD	Specific volume of supply duct air	ft^3/lbm
SPVZ(I)	Specific volume of zone air	ft^3/lbm
STLCC(K)	Leaving coil air temperature in outside air control method schedule	°F
STOA(K)	Outside air dry bulb temperature in outside air control method schedule	°F
TO(I)	Trunk duct air temperature at zone branches	°F
TOO	Default value of leaving coil air temperature	°F
TLCC(J)	Leaving coil air temperature	
TLCCA(J)	Absolute leaving coil air temperature	°R
TLCCF	Leaving coil air temperature(for fixed control method)	°F
TMIX	Entering coil air temperature	°F
TOA(J)	Outside air dry bulb temperature	°F
TPL	Plenum air temperature	°F
TPL1	Interim plenum air temperature	°F
TPLA	Assumed plenum air temperature	°F
TPR	Total pressure drop across return fan	in. of H_2O
TPS	Total pressure drop across supply fan	in. of H_2O
TR(J)	Return air temperature	°F
TSUPRZ(I)	Required zone air supply temperature	°F
TSUPZ(I)	Zone air supply temperature	°F
TSUPZI(I)	Zone air supply temperature after induction(for VAV system option)	°F
TWB(J)	Outside wet bulb temperature	°F
TZ(I,J)	Zone set point temperature	°F
UCZ	Ceiling "U" value	Btu/ft^2-°F
UD	Duct system "U" value	Btu/ft^2-°F
V	Design trunk duct velocity (assumed constant in trunk)	ft/min
VD	Design branch duct velocity (assumed constant in branch)	ft/min
WLCC(J)	Humidity ratio leaving the coils	lb of H_2O/ lb dry air
WMIX	Humidity ratio entering the coils	lb of H_2O/ lb dry air
WMIXA	Assumed plenum humidity ratio	lb of H_2O/ lb dry air

VARIABLE NAMES	DESCRIPTION	UNITS
WOA	Outside air humidity ratio	lb of H_2O/ lb dry air
WOAS	Saturated outside air humidity ratio	lb of H_2O/ lb dry air
WR	Return air humidity ratio	lb of H_2O/ lb dry air
WZ(I)	Zone humidity ratio	lb of H_2O/ lb dry air
YN1-YN6	Yes/No choice character	Character

APPENDIX C

PROGRAM USER'S GUIDE

DATA INPUT OPTIONS

A description of the input routine for the program contained in Appendix D is provided below. Its main purpose is to provide a user's guide to the program's input phase of execution. It can be used directly with the executable file of the program, if one is available. The program begins the run when the user types HVAC. It should be noted that the keyboard should be in the CAPS-LOCK-ON mode or the program will not recognize some of the required input. The required units for all input values will always be shown somewhere on the screen during the input. The user should ensure the correct units are used or erroneous results will be produced.

DEFAULT OPTIONS

The program begins by providing the user with a look at the constants used in the simulation. These include the specific heats of dry air, water vapor and liquid water, the maximum trunk and branch duct velocities, the assumed initial plenum temperature, the duct and ceiling "U" values, the fraction of lighting energy which is released directly into the plenum, the maximum outside air dry bulb temperature allowed for economizer operation, the fraction of total air volume leaked to the plenum out of the duct system and the maximum allowable leaving coil air temperature. The user has the option of changing any of these values by entering the number printed on the screen to the left of the constant's description and then entering the new value of the constant. The new constant will be recorded and the constants list again printed to the screen, showing the updated value. The units of each constant are included and care should be taken to match these with any changes made. The value "99" is entered if no changes are desired or when all changes have been completed. Any changes made during a particular run <u>are</u> <u>not</u> stored for future

runs. In the case where one or more of the constants will have to be a different constant value all or most of the time, and if the software source code is available, the user can change the default in the source code of the input routine.

SYSTEM/CONTROLS OPTIONS

The system type and leaving coil temperature control method are selected next. Each is chosen by entering the number to the left of the descriptions. The program will not allow for numeric entries other than one, two or three. If the fixed set point control method is chosen, the next prompt will be for the fixed set point value to be used. The program does not contain a default value, so one must be entered.

When option three, the outside air (dry bulb) control method, is selected, the program will then ask the user to indicate the schedule to be used to set the temperature of the air mixture leaving the coil based on a corresponding outside air dry bulb temperature. A message will appear on the screen asking whether or not the user wishes to enter or select an existing schedule. If a schedule is not to be selected or entered, select the "N" option. The program will then go back to the control method options and a different option may be selected. The program allows for the creation of a new file, edit of an existing file or use of an existing file. To use an existing file, the "U" option should be chosen and the existing file name entered. The program will then progress to the economizer options.

To create a new file, the "C" option should be selected. The next prompt will be for the entry of a file name. To enter a file name, the drive in which the file is to be stored, the file name and the extension may be entered. An input of up to fourteen alphanumeric characters, for example C:FILENAME.EXT, is allowed by the program. Then program will then ask for dry bulb temperatures

of the outside air and air mixture leaving the coil. A leaving coil air temperature for each outside air dry bulb temperature encountered in the twenty-four hour simulation must be included in this file. The input for this file is not limited to the twenty-four, or less, sets of temperatures which may be required for a single simulation. It can hold up to 150 sets of outside versus leaving coil air temperatures. Therefore, this file need only be set up once for a specific location and reused again and again. A data point of "999,999" must be entered after the last set of values. This point is an end of record mark and will tell the program that input is completed.

During execution, the program will search this file looking for an outside air temperature which corresponds to the outside air temperature for a given hour as input in the weather and zone independent file described below. When it finds an outside temperature within $\pm 0.5^{o}F$, it will set the leaving coil temperature based on the one that is attached to the outside temperature found in the file. If the program encounters an outside temperature without an associated leaving coil temperature, a message stating, "Outside air temperature encountered in hour X is beyond the range of your control schedule. Either your control method or schedule must be changed.", will be printed on the screen during the simulation. In this case, the program will run to completion, but no results will be printed. The user should make every effort to ensure that this does not happen because there is no option to stop the program and change the file. Therefore, all the data would have to be input again or another editor used to include the omitted set of data.

When editing an existing file, which has been chosen by selecting option "E", the program will display the first forty-eight set of values in the file and ask if the values to be edited

are shown. If they are, type "Y", the number to the left of the values and then the new values for the outside dry bulb temperature and corresponding leaving coil temperature. If they are not shown, type "N" and the program will display the next forty-eight values. Once the point has been edited, the program will ask if there are more points to edit. Either a "Y" or "N" response is required.

The next input is that of the minimum fraction of outside air which must be used in the simulation for ventilation purposes. This value is entered as the ratio of the volumetric flow (CFM) of outside air to the total volumetric flow entering the coils and must be a value between zero and one, inclusive. Once the minimum has been chosen, the manner by which the amount of outside air entering the system is controlled must be selected. The economizer choices will be printed to the screen and a value of one, two or three can be selected. A description of the principles that each choice uses for control is included in the section ECONOMIZER CONTROLS.

ZONE INDEPENDENT DATA INPUT

A separate permanent file is set up for data which are independent of the individual zones. It contains the hourly outside dry bulb and wet bulb air temperatures, plenum envelope load and assumed maximum relative humidity of the air mixture leaving the coils which will be used in the simulation. The plenum envelope load input must based on the assumed plenum temperature selected earlier in the default constants portion of the input. A message showing the assumed plenum temperature which will be used is shown on the screen. The assumed relative humidity leaving the coil input should be a value between 95% and 100%, input as %/100. This value corresponds to the the user's assumption of saturation conditions leaving the coil. Depending

on how deep the coil employed is, the average overall condition of a "saturated" air mixture leaving the coil may be slightly less than saturated.(i.e. Relative humidity less than 100%.)

As with the outside air control method, the program provides the option of whether to use or edit an existing file or to create a new file.There must be exactly twenty-four hours of data input in this file. After a "E", "C" or "U" choice is made, the filename is entered, as described above. To use an existing file, again the "U" option should be chosen.

When creating a file, the program allows for the option of having a constant or variable assumed relative humidity value exiting the coils. For a constant relative humidity, enter the value in units of percent relative humidity divided by 100. If a variable value is desired, enter any numeric value greater than one. Depending on the relative humidity option, the program will then ask for twenty-four values of the remaining three or four items. It will ask for the data by hour and the convention used for the data hour is that hour one is the period between midnight and one o'clock AM, etc. The program will automatically end taking data after twenty-four values. No special end of file marker is stored in the permanent file because there must always be exactly twenty-four hours of data.

A data file can be edited immediately after inputting the data for a new file by answering "Y" to the question asking such, or by selecting the "E" option for file use. The program will prompt for the hour of data to be edited. After a value between one and twenty-four is entered, the data existing for that hour in the file will be shown on the screen along with a request for the new data. Any hour can be edited as many times as required. The editing session is ended by entering a value of "99" for the hour of data to be edited. The program will only

recognize hourly values of one through twenty-four and "99" for editing options.

ZONE UNIQUE DATA INPUT

This is the largest permanent file set up by the program. It contains two types of data for each zone in the facility simulated. The first type is independent of the hour and includes the trunk duct distance from the supply fan exit to the zone branch duct, the length of the zone branch duct and the zone area. The second type contains hourly zone data for the sensible and latent loads, set point temperature, air volumetric flow rate, and lighting energy. If the VAV system is being simulated, the minimum volumetric flow rate is used instead of a constant value. All four options; using, editing and appending an existing file and creating a new file, are available for input of this data. To use an existing file, the "U" option should be selected and the existing filename entered.

To create a new file, the "C" option should be chosen, followed by the new filename. Prior to entering the data for any zone, the zones should be arranged and numbered sequentially, according to their distance away from the supply fan. It is very important that the "distance from the supply fan to the branch duct" value for zone one is less than, or equal to, the distance for zone two and the distance for zone two less than that of zone three and so on. This is because the program calculates the temperature change in the trunk duct by sections. The section lengths are determined by subtracting the distance to the branch duct for zone six, for example, from that of zone five. If this is a negative value, a temperature drop would be realized instead of a temperature rise; and vice versa.

Once the zones have been organized and numbered, the program will ask for input of the distance from the supply fan to

the branch duct, the length of the branch duct and the area for the first zone. It will number the first zone entered as zone one and all subsequent zones sequentially. The zones can be named later as described in the RESULTS PRINTING OPTIONS section. The next input will be for the zone's hourly sensible and latent loads, set point temperature, air volume rate and lighting energy. The zone and hour to be input will be shown on the screen prior to input. The program will only take twenty-four hours of input and then ask if there are more zones. If there is data for another zone, a "Y" response should be made and the same procedure as outlined above should be followed. When the data for the last zone has been input, the "N" option should be selected when the program prompts for additional zone data input.

The program will not allow input of a trunk duct length less than the previous zone's. For the case where a zone closer to the supply fan is omitted in the initial input, the file creation should continue until completion of input of all data except the excluded zone. Then, after the "N" option is chosen for the "Are there more zones for data input?(Y/N)" prompt, the simulation can be terminated and rerun. Here, for all files previously created above, the "U" option can be chosen. For the zone unique data file, the "A" option should be chosen and the excluded zone input.

After the data for the last zone has been input, the program inserts three values of zero to the end of the file. It does this to aid in future reading of the file. If input is accomplished with another editor, these three zeros must be included as the last entry. At this point, the prompt will be "Do you want to edit this data?". When editing is desired, follow the procedures below.

To edit an existing data file, the "E" option should be chosen along with the existing filename. If a filename is entered

which does not correspond to an existing file, the program execution will terminate. The program will then ask which zone is to be edited. A number from one to the last zone in the file should be entered. The program will ask for this number again if the number entered is greater than the number of zones currently in the file. Once the zone has been chosen, either the hourly independent or hourly data can be edited. To edit the length and area data, enter a value of zero. The current data in the file will be shown and a request to enter the new data. If the value entered for the trunk duct distance from the supply fan is greater than the distance input for this same distance in the next zone or less than the value in the previous zone, the program will state that the distance should be between the two previously input values. Then it will ask if the editing is hourly independent or hourly in the chosen zone again. To edit hourly data, enter the hour of the data to be edited. The program will display the current data and ask for the new data.

Once the point has been edited, the program will ask for the zone number of the next edit. The new zone number can be entered and the procedure above followed or a value of "99" can be entered if editing is complete. There is no check for correctness of the edited hourly data, since there are no restrictions which hold true for every case. Therefore it is suggested that, after the first simulation run, the option to receive a hard copy of the input data should be chosen as described in the section RESULTS PRINTING OPTIONS in order to check the accuracy of the data files.

The final zone unique data file input option is appending data to an existing file. The option "A" should be chosen with the existing file name. The program will then display the trunk duct distance from the supply fan to the branch duct to each zone and ask for the number of the new zone. The data for a new zone will be inserted in the file between the existing zone

which is numbered with the same number of the new zone and the one immediately before it. For example, if an existing file contains data for four zones and a new zone four is desired to be entered, the program will number the new zone as four and the existing zone numbered four will be renumbered as five. The length of the trunk duct to the branch of the new zone must between the lengths for the existing zones three and four. An example is also displayed on the screen. Once the new zone number is entered, the program will prompt for the new hourly independent data. If the trunk duct length is too long or too short, the program will state this, then request that the number of the new zone be reentered and ask for the new data. Then, the zone hourly data should be input as described earlier in this section.

After twenty-four hours of data has been entered, the program will ask if there are any more zones to be added. For additional zones, answer "Y" and follow the procedures immediately preceding. If all the required data has been entered, answer "N" and the program will ask if data editing is desired. Any data in the file, including the zone just added, can be edited by entering the response "Y" and following the procedures on editing an existing file outlined above.

When the system chosen for simulation is the VAV with induction reheaters, an additional file must be used. Since the air mixture flow rate to each zone is allowed to vary according to the space load requirement, minimum and maximum flow rates must be entered for each zone. The minimum rate was entered previously in the zone unique data file, so only the maximum rate must still be entered. Also, the maximum flow rate through the induction system must be input. The create, edit, append and use options are all available for this input. The flow rate values must be entered as non-negative values for the program to run correctly. The amount of data input is restricted to the number of zones contained in

the zone unique data file above. To use an existing file, select the "U" option and enter the existing file name. The program will expect the file to have data for at least as many zones as are contained in the zone unique data file.

The program will read a file which contains data for a greater number of zones than that which is included in the zone unique file above, but it will only read up to the number of zones required for simulation. The data for the remaining zones may be lost during subsequent editing or appending sessions.

Procedures for editing and creating this file are the same as discussed previously, except the input/edit is limited to the correct number of zones. When using the "A" option to append an existing file, the number of zones of data contained in the existing file must also be specified. The program will then ask for input of additional zones of data, up to the number of zones contained in the zone unique data file. Editing can also be accomplished after appending.

FAN CONTROL OPTIONS

The last input options concern the supply and return fans used. These options are not stored in a permanent file for future simulations and must be selected prior to each simulation. The program assumes a supply fan will be used. Therefore, it first asks if the fan motor is in the air stream. A "Y" response will produce prompts for the motor and fan design efficiencies. A "N" response will produce only a prompt for the design fan efficiency. In the case where the motor is not in the air stream, the program will set the motor efficiency to 100%. Efficiencies are input as values of between zero and one. An input value of greater than one will require reinput. The next data required is the total pressure drop across the supply fan. The program contains no check for accuracy on the value input. Therefore, a

reinput prompt will not be produced if a negative pressure drop is entered. Next, the program will give the option of whether or not to use return fan in the simulation. If a "Y" response is given, the same input as was required for the supply fan will be required. When a response of "N" is given, no other return fan information is requested.

Finally, when using the VAV system, the method of fan control must be selected. The program will display the four choices described in the section FAN CONTROL and prompt for entry of the number to the left of the method desired. Only numbers one through four will be recognized. Then, the program will display the coefficients to be used in the part loading equations. The coefficients for a cycling fan will be displayed when the cycling system is being simulated. These coefficients can be changed by selecting letter to the left of the coefficient. All methods of control have four coefficients, designated "A" through "D". If no changes are required, an input of "E" must be entered. The program does not recognize inputs other than "A" through "E".

RESULTS PRINTING OPTIONS

Upon completion of a simulation execution, the program will prompt for the name of the permanent file in which the results are to be stored. All results, including the summary of simulation input and the output, will be stored to this permanent file no matter what hard copy printing options are subsequently selected. All these results will also be scrolled on the screen, after the printing options are selected.

When the permanent file has been selected, the program will then give the option of printing a hard copy of the summary of inputs, output results and all permanent input files used in the particular simulation. Examples of these hard copies are shown in Appendix A. The printing options are contained in three

successive statements, each requiring a "Y" or "N" response. Since the results data are also contained in a permanent file, they can be printed later with the microcomputer's own software.

SUMMARY

It is felt that the input routine developed for use with this program provides all instructions required for successful data input. These detailed instructions are displayed during input for every simulation executed. If a prompt keeps repeating, even after an option has been entered, the user should check to ensure the computer keyboard is in the "CAPS ON" mode. There are numerous checks in the program which attempt to assure correct entry of input data, but it is again suggested that the input files be printed after the first simulation to check the data. Finally, due to the formats used for reading the input data, if a character (i.e. "a", "B", "F", etc.) value is entered where a numerical value is required, the program execution will terminate. In this case, reinput of much of the data may be required.

APPENDIX D

PROGRAM SOURCE CODE

```
$NOFLOATCALLS
$STORAGE:2
C=======================================================================
C=========THE FOLLOWING IS A TWENTY FOUR HOUR SIMULATION OF=========
C=========AN HVAC SYSTEM OPERATION.  IT INCLUDES OPTIONS TO=========
C=========VARY THE SYSTEM FROM A CONSTANT VOLUME TERMINAL===========
C=========REHEAT SYSTEM TO A VARIABLE VOLUME WITH INDUCTION=========
C=========REHEAT SYSTEM TO A CYCLING (SINGLE ZONE) SYSTEM.==========
C=========THERE IS THE CHOICE OF THREE METHODS OF CONTROL OF========
C=========THE LEAVING COIL AIR TEMPERATURE (FIXED SET POINT,========
C=========ZONE CONTROLLED, OR OUTSIDE AIR CONTROLLED).  THERE=======
C=========ARE ALSO THREE METHODS OF ECONOMIZER CONTROL (NO==========
C=========ECONOMIZER, DRY BULB AND ENTHALPY CONTROLLED).============
C=========THE SUPPLY AND OPTIONAL RETURN FANS CAN HAVE CONSTANT=====
C=========OR VARIABLE SPEED MOTORS, INLET DAMPERS, DISCHARGE========
C=========DAMPERS, OR CAN BE SIMULATED AS CYCLING.==================
C=========WHEREVER POSSIBLE, DEFAULT VALUES HAVE BEEN INCLUDED======
C=========WITH THE OPTION FOR CHANGE TO FIT THE SITUATION.==========
C=======================================================================
C=========THE OUTPUTS FROM THIS PROGRAM INCLUDE LOADS ON THE========
C=========COOLING COILS, PREHEATER, ZONE REHEATERS, LEAVING=========
C=========COIL AIR CONDITIONS, ZONE PRIMARY AND SECONDARY AIR=======
C=========FLOW RATES, AND THE PERCENTAGE OF OUTSIDE AIR USED.=======
C=========(WHEN THE CYCLING SYSTEM IS SIMULATED, THE RUNNING========
C=========TIME PER HOUR IS ALSO OUTPUT.)============================
C=========BOTH INPUT AND OUTPUT FILES CAN BE PRINTED, IF DESIRED.===
C=======================================================================
C=========THIS PROGRAM WAS DEVELOPED BY CAPTAIN MICHAEL K. REARDON==
C=========UNDER THE TECHNICAL DIRECTION OF DR. JEROLD W. JONES,=====
C=========PROFESSOR, MECHANICAL ENGINEERING DEPARTMENT, THE=========
C=========UNIVERSITY OF TEXAS AT AUSTIN.============================
C=======================================================================
      PROGRAM HVAC
C
      IMPLICIT REAL (A-H,L,P-Z)
      CHARACTER YN1,YN2,YN3,FCHOOZ,YN4,YN5,YN6,FCHUZZ,FCHUZS,FCHUZM,
     +ICT
      CHARACTER*14 FNAME,FZNAME,SCHDLE,MAXCFM,OUTFILE
      CHARACTER*20 FANTYP
      DIMENSION RUNTME(24)
      COMMON/AAAAA/CFM(50,24),CFMZ(50,24),N,JX,IMOA,ICNTRL,ISYSTM,
     +MIN,MN,AD(50),ADZ(50),ACFM(50),ACFMZ(50),FRHR(24),FRHRA
      COMMON/BBBBB/DTD(50),DTDT(50),DTDZ(50),V,VD,L(50),LZ(50),TPL,
     +TO(50),TOO,UD
      COMMON/CCCCC/QDUCT
      COMMON/DDDDD/CPMMIX,CPMLCC,CPMR,CPA,CPV,CPL,HGLCC,HLCC,HOA,HRA
      COMMON/EEEEE/PI,TSUPZ(50),IFLAG9
      COMMON/FFFFF/SPVA(50),UCZ,AZ(50),QLGZ(50,24),TZ(50,24),TOA(24)
```

```
     +,TWB(24),FRQLGT,TPL1,TPLA,FLUXW,QPLW(50),AMXECON
      COMMON/GGGGG/QSZ(50,24),QLZ(50,24),TSUPRZ(50),DTRH(50),QRHZ(50,24)
      COMMON/HHHHH/RH(24),PTOA(24),TMIX,SPVZ(50),WOAS,WOA,WLCC(24),
     +WZ(50),WR,WMIX,IFLAG1,TLCC(24),TR(24),IWCHK,SPVSD,PTOAM,HG,
     +TLCCF,IFLAG2,IFLAG3,IFLAG4,STOA(150),STLCC(150),TLCCA(24)
      COMMON/IIIII/SFHP,RFHP,TPS,TPR,SFANn,RFANn,SMOTn,RMOTn,DTSF,
     +DTRF,SFPLD(4),RFPLD(4),AMXTLCC
      COMMON/JJJJJ/QCCL(24),QPH(24),FRDL
      COMMON/KKKKK/CFMZMX(50),CFMZMN(50,24),CFMZIM(50),CFMZI(50,24),
     +TSUPZI(50),SPVI(50),SPVS(50),IFLAG5,IFLAG6,IFLAG7,IFLAG8(50)
C
C
C==========INITIAL CONSTANT DEFAULT VALUES========================
C
      WRITE(*,373)
 373  FORMAT(//,22X,'INSURE THE KEYBOARD IS IN THE',/,27X,
     +'"CAPS LOCK ON" MODE.')
C
      PI=4*ATAN(1.0)
      T00=55.
      KCHNGE=0
C
      CPA=0.236585
      CPV=0.448833
      CPL=1.000764
      V=1000.
      VD=500.
      TPLA=81.
      UD=0.20000
      UCZ=0.3
      FRQLGT=0.6
      FRDL=0.05
      AMXECON=62.5
      AMXTLCC=68.0
C
 104  WRITE(*,'(///A/)')' THE DEFAULT VALUES FOR CONSTANTS ARE.'
      WRITE(*,279) CPA
 279  FORMAT(3X,'  (1) SPECIFIC HEAT OF DRY AIR(BTU/LBM-oF)',11X,
     +F12.7)
      WRITE(*,280) CPV
 280  FORMAT(3X,'  (2) SPECIFIC HEAT OF WATER VAPOR(BTU/LBM-oF)',7X,
     +F12.7)
      WRITE(*,281) CPL
 281  FORMAT(3X,'  (3) SPECIFIC HEAT OF LIQUID WATER(BTU/LBM-oF)',
     +6X,F12.7)
      WRITE(*,282) V
 282  FORMAT(3X,'  (4) MAXIMUM TRUNK DUCT VELOCITY(FT/MIN)',12X,
     +F12.7)
```

```
      WRITE(*,283) VD
 283  FORMAT(3X,'  (5) MAXIMUM ZONE BRANCH DUCT VELOCITY(FT/MIN)',
     +6X,F12.7)
      WRITE(*,284) TPLA
 284  FORMAT(3X,'  (6) ASSUMED PLENUM TEMPERATURE(oF)',17X,F12.7)
      WRITE(*,285) UD
 285  FORMAT(3X,'  (7) DUCT "U" (BTU/SQFT-oF-HR)',22X,F12.7)
      WRITE(*,286) UCZ
 286  FORMAT(3X,'  (8) CEILING "U" (BTU/SQFT-oF-HR)',19X,F12.7)
      WRITE(*,287) FRQLGT
 287  FORMAT(3X,'  (9) FRACTION OF LIGHTING ENERGY ENTERING THE PL',
     +'ENUM',F12.7)
      WRITE(*,383) AMXECON
 383  FORMAT(3X,' (10) DRY BULB ECONOMIZER SHUT OFF TEMPERATURE(oF)'
     +,3X,F12.7)
      WRITE(*,277) FRDL
 277  FORMAT(3X,' (11) DUCT LEAKAGE(% OF TOTAL CFM ACROSS COIL/100)'
     +,3X,F12.7)
      WRITE(*,384) AMXTLCC
 384  FORMAT(3X,' (12) MAXIMUM LEAVING COIL AIR TEMPERATURE(oF)'
     +,7X,F12.7,////)
C
C=========OPTION TO CHANGE CONSTANT DEFAULT VALUES=================
C
      WRITE(*,*) 'IF ANY OF THESE VALUES NEED TO BE CHANGED, TYPE'
      WRITE(*,'(A\)') ' THE NUMBER TO THE LEFT, IF THEY ARE OKAY TYPE "9
     +9"  '
      READ(*,*) ICHK
      IF(ICHK.EQ.99) GOTO 103
      IF(ICHK.LT.1 .OR. ICHK.GT.12) THEN
        WRITE(*,250)
 250    FORMAT(/,/,/,/,/,/,/,/,' UNRECONIZABLE ENTRY--TRY AGAIN',/)
        GOTO 104
      ENDIF
C
C========CHECK TO SEE IF ANY CONSTANTS HAVE BEEN CHANGED============
C
            KCHNGE=1+KCHNGE
      WRITE(*,'(////A\)') ' ENTER DESIRED VALUE FOR THE CONSTANT. '
      IF(ICHK.EQ.1) READ(*,*) CPA
      IF(ICHK.EQ.2) READ(*,*) CPV
      IF(ICHK.EQ.3) READ(*,*) CPL
      IF(ICHK.EQ.4) READ(*,*) V
      IF(ICHK.EQ.5) READ(*,*) VD
      IF(ICHK.EQ.6) READ(*,*) TPLA
      IF(ICHK.EQ.7) READ(*,*) UD
      IF(ICHK.EQ.8) READ(*,*) UCZ
      IF(ICHK.EQ.9) READ(*,*) FRQLGT
```

```
      IF(ICHK.EQ.10) READ(*,*) AMXECON
      IF(ICHK.EQ.11) READ(*,*) FRDL
      IF(ICHK.EQ.12) READ(*,*) AMXTLCC
      GOTO 104
 103  CONTINUE
C
        IF(FRDL.LT.0.00001) FRDL=0.0
C
C=============SYSTEM TYPE CHOICE==================================
C
      WRITE(*,290)
 290  FORMAT(/,/,/,/,/,/,1X,'ENTER THE TYPE OF SYSTEM TO BE ',
     +'SIMULATED BY SELECTING',/,1X,'THE NUMBER TO THE LEFT OF THE',
     +' SYSTEM DESIRED.',/,/,/,5X,'(1)  TERMINAL REHEAT',/,
     +5X,'(2)  VARIABLE AIR VOLUME WITH INDUCTION REHEATERS',/,
     +5X,'(3)  CYCLING SYSTEM',/,/)
C
 116  WRITE(*,'(A\)') ' YOUR CHOICE(1/2/3)?  '
      READ(*,*) ISYSTM
      IF((ISYSTM.LT.1).OR.(ISYSTM.GT.3)) THEN
        WRITE(*,250)
        WRITE(*,290)
        GOTO 116
      ENDIF
C
C==========CONTROL METHOD CHOICE==================================
C
 144  WRITE(*,291)
 291  FORMAT(/,/,/,/,/,/,1X,'ENTER THE TYPE OF CONTROL METHOD TO B',
     +'E USED',/,1X,'BY SELECTING THE NUMBER TO THE LEFT OF THE ME',
     +'THOD DESIRED ',/,/,1X,'THE TEMPERATURE LEAVING THE COOLING ',
     +'COIL WILL BE;',/,5X,'(1)  FIXED SET POINT',/,
     +5X,'(2)  ZONE CONTROLLED',/,
     +5X,'(3)  OUTSIDE AIR (DRY BULB) CONTROLLED',/,/)
C
 117  WRITE(*,'(A\)') ' YOUR CHOICE(1/2/3)?  '
      READ(*,*) ICNTRL
      IF((ICNTRL.LT.1).OR.(ICNTRL.GT.3)) THEN
        WRITE(*,250)
        WRITE(*,291)
        GOTO 117
      ELSEIF(ICNTRL.EQ.1) THEN
C
C=========INPUT OF LEAVING COIL TEMPERATURE FOR FIXED===============
C=========TEMPERATURE CONTROL METHOD===============================
C
        WRITE(*,'(/////A)') ' ENTER THE COOLING COIL LEAVING AIR '
        WRITE(*,'(A\)') ' TEMPERATURE(oF) TO BE FIXED--- '
```

```
      READ(*,*) TLCCF
     ELSEIF(ICNTRL.EQ.3) THEN
 143  WRITE(*,296)
C
C=========INPUT OF LEAVING COIL TEMPERATURE FOR OUTSIDE=============
C=========AIR CONTROLLED CONTROL METHOD============================
C
 296  FORMAT(/,/,/,/,/,1X,'TO USE THIS CONTROL METHOD, A SCHEDULE'
     +,' OF COOLING',/,1X,'COIL LEAVING TEMPERATURES(TLCC) VERSUS ',
     +'OUTSIDE DRY',/,1X,'BULB TEMPERATURES(TOA) MUST BE ENTERED.',
     +/,/,5X,'DO YOU HAVE THIS SCHEDULE FOR THE RANGE OF OUTSIDE',
     +/,5X,'AIR TEMPERATURES WHICH WILL BE ENCOUNTERED(Y/N)?  ',\)
      READ(*,'(A1)') YN1
      IF(YN1.NE.'Y'.AND.YN1.NE.'N') GOTO 143
      IF(YN1.EQ.'N') GOTO 144
C
C=========OUTSIDE AIR CONTROL SCHEDULE INPUT/EDIT==================
C
 147  WRITE(*,288)
      READ(*,'(A1)') FCHUZS
      IF(FCHUZS.EQ.'E') GOTO 148
      IF(FCHUZS.EQ.'C') GOTO 149
      IF(FCHUZS.EQ.'U') GOTO 150
      WRITE(*,250)
      GOTO 147
C
 148  NFLAG=1
      WRITE(*,252)
      READ(*,253) SCHDLE
      GOTO 151
C
 149  NFLAG=2
      WRITE(*,254)
      READ(*,253) SCHDLE
      GOTO 151
C
 150  NFLAG=3
      WRITE(*,255)
      READ(*,253) SCHDLE
C
 151  IF(NFLAG.EQ.2) THEN
        OPEN(5,FILE=SCHDLE,FORM='FORMATTED',STATUS='NEW')
        WRITE(*,297)
 297    FORMAT(/,/,/,/,/,/,1X,'ENTER THE OUTSIDE DRY BULB TEMPER'
     +'ATURE(oF) AND',/,1X,'CORRESPONDING LEAVING COIL TEMPERATURE'
     +'(oF).',/,1X,'ENTER "999,999" IF SCHEDULE IS COMPLETE.',/,/)
        NSTEP=1
 145    READ(*,*) STOA(NSTEP),STLCC(NSTEP)
```

```
          IF(STOA(NSTEP).EQ.999.0) GOTO 146
          NSTEP=NSTEP+1
          GOTO 145
C
 146      DO 1 I=1,NSTEP
 1        WRITE(5,*) STOA(I),STLCC(I)
          REWIND 5
          CLOSE(5)
 152      WRITE(*,'(////A\)') ' DO YOU WANT TO EDIT THIS DATA(Y/N)?  '
          READ(*,'(A1)') YN2
          IF(YN2.NE.'Y'.AND.YN2.NE.'N') GOTO 152
          IF(YN2.EQ.'Y') GOTO 153
          GOTO 164
C
        ELSEIF(NFLAG.EQ.3) THEN
          OPEN(5,FILE=SCHDLE,FORM='FORMATTED',STATUS='OLD')
          REWIND 5
          CLOSE(5)
          GOTO 164
C
        ELSEIF(NFLAG.EQ.1) THEN
          GOTO 153
        ENDIF
C
 153    OPEN(5,FILE=SCHDLE,FORM='FORMATTED',STATUS='OLD')
        REWIND 5
        NSTEP=1
C
 154    READ(5,*) STOA(NSTEP),STLCC(NSTEP)
        IF(STOA(NSTEP).EQ.999.0) THEN
          REWIND 5
          GOTO 155
        ENDIF
        NSTEP=NSTEP+1
        GOTO 154
C
 155    CONTINUE
        DO 2 I=1,NSTEP,48
          WRITE(*,298)
 298      FORMAT(/,/,1X,3(3X,'POINT',3X,'TOA',4X,'TLCC'),/)
          IP=I
          JP=I+16
          KP=I+32
 161      DO 3 J=1,16
            IPP=IP+(J-1)
            JPP=JP+(J-1)
            KPP=KP+(J-1)
            IF(IPP.GE.NSTEP) GOTO 158
```

```
          IF(JPP.GE.NSTEP) GOTO 157
          IF(KPP.GE.NSTEP) GOTO 156
C
          WRITE(*,299) IPP,STOA(IPP),STLCC(IPP),JPP,STOA(JPP),
     +STLCC(JPP),KPP,STOA(KPP),STLCC(KPP)
 299      FORMAT(2X,3(3X,I3,2(2X,F6.2)))
          GOTO 158
C
156       WRITE(*,300) IPP,STOA(IPP),STLCC(IPP),JPP,STOA(JPP),
     +STLCC(JPP)
 300      FORMAT(2X,2(3X,I3,2(2X,F6.2)))
          GOTO 158
C
 157      WRITE(*,301) IPP,STOA(IPP),STLCC(IPP)
 301      FORMAT(5X,I3,2(2X,F6.2))
 158      CONTINUE
 3      CONTINUE
C
 159    WRITE(*,302)
 302    FORMAT(1X,'DO YOU WANT TO EDIT ANY OF THESE POINTS(Y/N)? '
     +,\)
        READ(*,'(A1)') YN3
        IF(YN3.NE.'Y'.AND.YN3.NE.'N') GOTO 159
        IF(YN3.EQ.'N') GOTO 162
 160    WRITE(*,'(A\)')' WHICH POINT?(ENTER NUMBER OF THE POINT) '
        READ(*,*) IPPICK
        ILARGE=MINO(KPP,NSTEP-1)
        IF((IPPICK.LT.IP).OR.(IPPICK.GT.ILARGE)) THEN
          WRITE(*,303) IP,ILARGE
 303      FORMAT(/,1X,'POINT TO BE EDITTED MUST BE BETWEEN',1X,I3,1X,'
     +AND',1X,I3,'.',/)
          GOTO 159
        ELSE
          WRITE(*,'(//A\)')' ENTER NEW TOA(oF) AND NEW TLCC(oF)    '
          READ(*,*) STOA(IPPICK),STLCC(IPPICK)
          GOTO 161
        ENDIF
 162    CONTINUE
 2     CONTINUE
C
 163   WRITE(*,'(///A\)')' DO YOU WANT TO EDIT THIS DATA AGAIN(Y/N)? '
       READ(*,'(A1)') YN5
       IF(YN5.NE.'Y'.AND.YN5.NE.'N') GOTO 163
       IF(YN5 EQ 'Y') GOTO 155
       DO 4 I=1,NSTEP
 4     WRITE(5,*) STOA(I),STLCC(I)
       REWIND 5
       CLOSE(5)
```

```
      ENDIF
C
C=========READS SCHEDULE INPUT FILE TO MAIN PROGRAM================
C
 164  CONTINUE
      IF(ICNTRL.EQ 3) THEN
        OPEN(5,FILE=SCHDLE,FORM='FORMATTED',STATUS='OLD')
        NSTEP=1
 165    READ(5,*) STOA(NSTEP),STLCC(NSTEP)
        IF(STOA(NSTEP).EQ.999.0) THEN
          REWIND 5
          CLOSE(5)
        ELSE
          NSTEP=NSTEP+1
          GOTO 165
        ENDIF
      ENDIF
C
C=========INPUT OF MINIMUM FRACTION OF OUTSIDE AIR REQUIRED=========
C
 111  WRITE(*,292)
 292  FORMAT(/,/,/,/,/,/,1X,'ENTER THE MINIMUM FRACTION(OUTSIDE AIR'
     +' VOLUME/TOTAL AIR VOLUME)',/,1X,'OF OUTSIDE AIR WHICH CAN ',
     +'BE USED (0.0-1.0)?  ',\)
      READ(*,*) PTOAM
      IF((PTOAM.LT.0.0).OR.(PTOAM.GT.1.0)) THEN
        WRITE(*,250)
        GOTO 111
      ENDIF
C
C=========ECONOMIZER CONTROL CHOICE==============================
C
      WRITE(*,293)
 293  FORMAT(/,/,/,/,/,1X,'ENTER THE METHOD TO BE USED FOR OUTSIDE '
     +,/,1X,'AIR CONTROL.',/)
      WRITE(*,294) PTOAM
 294  FORMAT(4X,'(1)  NONE, THE FRACTION OF OUTSIDE AIR WILL',/,
     +9X,'ALWAYS REMAIN AT',F5.2,/,
     +4X,'(2)  OUTSIDE DRY BULB TEMPERATURE CONTROLLED',/,
     +4X,'(3)  ENTHALPY CONTROLLED',/,/)
C
 118  WRITE(*,'(A\)') ' YOUR CHOICE (1/2/3)?  '
      READ(*,*) IMOA
      IF((IMOA.LT.1).OR.(IMOA.GT.3)) THEN
        WRITE(*,250)
        WRITE(*,293)
        GOTO 118
      ENDIF
```

```
C
C==========HOURLY WEATHER DATA AND DATA INDEPENDENT OF ZONE======
C
 105  WRITE(*,314)
 314  FORMAT(/,/,/,/,/,/,/,1X,'THE NEXT INPUTS WILL BE FOR HOURLY ',
     +'OUTSIDE DRY',/,1X,'BULB AND WET BULB TEMPERATURES, PLENUM ',
     +'WALL LOADS, AND',/,1X,'RELATIVE HUMIDITY LEAVING THE COILS.'
     +,/,/,/,/)
      WRITE(*,257) TPLA
 257  FORMAT(5X,'NOTE: THE PLENUM WALL LOAD SHOULD BE BASED ON',/,
     +5X,'AN ASSUMED PLENUM TEMPERATURE OF',F7.2,'(oF).',/,/)
      WRITE(*,288)
 288  FORMAT(/,' DO YOU WISH TO EDIT AN EXISTING DATA FILE?(TYPE E)'
     +,/,' CREATE A NEW DATA FILE?(TYPE C), OR',
     +/,' USE DATA FROM AN EXISTING FILE(TYPE U)?  ',\)
      READ(*,251) FCHOOZ
 251  FORMAT(A1)
      IF(FCHOOZ.EQ.'E') GOTO 107
      IF(FCHOOZ.EQ.'C') GOTO 108
      IF(FCHOOZ.EQ.'U') GOTO 109
      WRITE(*,250)
      GOTO 105
C
 107  JFLAG=1
      WRITE(*,252)
 252  FORMAT(/,/,' ENTER ''DRIVE:FILENAME.EXT'' OF FILE TO BE ',
     +'EDITTED  ',\)
      READ(*,253) FNAME
 253  FORMAT(A14)
      GOTO 110
C
 108  JFLAG=2
      WRITE(*,254)
 254  FORMAT(/,/,' ENTER ''DRIVE:FILENAME.EXT'' OF FILE TO BE '
     +'CREATED ',\)
      READ(*,253) FNAME
      GOTO 110
C
 109  JFLAG=3
      WRITE(*,255)
 255  FORMAT(/,/,' ENTER ''DRIVE:FILENAME.EXT'' OF FILE TO BE '
     +'USED  ',\)
      READ(*,253) FNAME
C
 110  IF(JFLAG.EQ.2) THEN
C
C=========INPUT OF ASSUMED RELATIVE HUMIDITY LEAVING THE COILS======
C
```

```
180    WRITE(*,315)
315    FORMAT(/,/,1X,'FOR THE RELATIVE HUMIDITY LEAVING THE COILS',
      +/,1X,'YOU HAVE THE CHOICE OF EITHER INPUTTING HOURLY VALUES',/
      +,1X,'OR ENTERING A CONSTANT VALUE TO BE USED FOR THE ENTIRE',/
      +,1X,'24 HOUR PERIOD OF SIMULATION.',/,/)
       WRITE(*,316)
316    FORMAT(1X,'FOR A CONSTANT RELATIVE HUMIDITY, ENTER THE VALUE
      +',/,1X,'CHOSEN(0.0-1.0)',
      +/,1X,'FOR A VARIABLE RELATIVE HUMIDITY, ENTER A VALUE GREATER'
      +,/,1X,'THAN 1.0.  ',\)
       READ(*,*) RHPICK
       IF(RHPICK.LT.0.0) THEN
         WRITE(*,250)
         GOTO 180
       ELSEIF((RHPICK.GE.0.0).AND.(RHPICK.LE.1.0)) THEN
         DO 34 I=1,24
34       RH(I)=RHPICK
         IRHFLAG=0
       ELSE
         IRHFLAG=1
       ENDIF
       OPEN(7,FILE=FNAME,FORM='FORMATTED',STATUS='NEW')
       WRITE(*,317)
317    FORMAT(/,/,1X,'ENTER THE OUTSIDE DRY BULB TEMPERATURE(oF),',
      +/,1X,'THE OUTSIDE WET BULB TEMPERATURE(oF),')
       IF(IRHFLAG.EQ.0) THEN
         WRITE(*,*) 'AND THE PLENUM WALL LOAD(BTU/HR) FOR '
       ELSE
         WRITE(*,318)
318      FORMAT(1X,'THE PLENUM WALL LOAD(BTU/HR) AND RELATIVE',/
      +,1X,'HUMIDITY FOR ')
       ENDIF
       DO 6 I=1,24
         WRITE(*,256) I,I-1,I
256      FORMAT(/,1X,'HOUR ',I2,'(',I2,':00-',I2,':00) ')
         IF(IRHFLAG.EQ.0) THEN
           READ(*,*) TOA(I),TWB(I),QPLW(I)
         ELSE
           READ(*,*) TOA(I),TWB(I),QPLW(I),RH(I)
         ENDIF
6      WRITE(7,*) TOA(I),TWB(I),QPLW(I),RH(I)
       REWIND 7
       CLOSE(7)
C
113    WRITE(*,'(//A\)') ' DO YOU WANT TO EDIT THIS DATA(Y/N)?  '
       READ(*,251) YN3
       IF(YN3.NE.'Y' .AND. YN3.NE.'N') GOTO 113
       IF(YN3.EQ.'Y') GOTO 112
```

```
        GOTO 114
C
      ELSEIF(JFLAG.EQ.3) THEN
        OPEN(7,FILE=FNAME,FORM='FORMATTED',STATUS='OLD')
        REWIND 7
        CLOSE(7)
        GOTO 114
C
      ELSEIF(JFLAG.EQ.1) THEN
        GOTO 112
      ENDIF
C
 112  OPEN(7,FILE=FNAME,FORM='FORMATTED',STATUS='OLD')
      REWIND 7
 115  WRITE(*,'(//A)') ' ENTER THE HOUR OF DATA TO BE EDITTED(1-24)'
      WRITE(*,'(A\)') ' OR "99" IF EDITING IS COMPLETE.  '
      READ(*,*) IHR
      IF(IHR.EQ.99) THEN
        CLOSE(7)
        GOTO 114
      ENDIF
      IF(IHR.LT.1 .OR. IHR.GT.24) THEN
        WRITE(*,250)
        GOTO 115
      ENDIF
      DO 7 I=1,24
 7    READ(7,*) TOA(I),TWB(I),QPLW(I),RH(I)
      REWIND 7
      WRITE(*,259) IHR,TOA(IHR),TWB(IHR),QPLW(IHR),RH(IHR)
 259  FORMAT(/,/,/,' EXISTING DATA FOR HOUR ',I2,/,/,5X,' DRY BULB',
     +' TEMPERATURE(oF) ',F11.2,/,5X,' WET BULB TEMPERATURE(oF) ',
     +F11.2,/,5X,' PLENUM WALL LOAD(BTU/HR) ',F11.2,/,5X,' RELATIVE'
     +,' HUMIDITY(%/100) ',F11.2)
      WRITE(*,258) IHR
 258  FORMAT(//,' ENTER NEW DATA FOR HOUR ',I2,2X,\)
      READ(*,*) TOA(IHR),TWB(IHR),QPLW(IHR),RH(IHR)
      DO 8 I=1,24
 8    WRITE(7,*) TOA(I),TWB(I),QPLW(I),RH(I)
      CLOSE(7)
      GOTO 112
C
 114  CONTINUE
C
C=========INPUT OF ZONE UNIQUE DATA(FOR VAV SYSTEMS, THE CFM========
C=========ENTERED WILL BE THE MINIMUM CFM REQUIRED=================
C
 119  WRITE(*,'(/////A/)')' THE NEXT INPUTS WILL BE ZONE UNIQUE DATA.'
      WRITE(*,*) 'DO YOU WISH TO EDIT AN EXISTING DATA FILE?(TYPE E)'
```

```
      WRITE(*,*) 'CREATE A NEW DATA FILE?(TYPE C)'
      WRITE(*,*) 'USE AN EXISTING DATA FILE?(TYPE U)'
      IF(ISYSTM.EQ.3) GOTO 167
      WRITE(*,*)'ADD ADDITIONAL ZONES TO AN EXISTING DATA FILE?(TYPE A)'
 167  WRITE(*,347)
 347  FORMAT(/,/,/,5X,'NOTE: EXISTING FILES CAN BE EDITTED WITH THE'
     +,/,5X,'USE OF AN EDITOR PROGRAM.  DELETING DATA FOR AN ENTIRE'
     +,/,5X,'ZONE CAN ONLY BE DONE WITH AN EDITOR PROGRAM.',/,/,/)
      WRITE(*,'(/A\)') ' YOUR CHOICE?  '
      READ(*,251) FCHUZZ
      IF(FCHUZZ.EQ.'E') GOTO 120
      IF(FCHUZZ.EQ.'C') GOTO 121
      IF(FCHUZZ.EQ.'U') GOTO 122
      IF(FCHUZZ.EQ.'A'.AND.ISYSTM.NE.3) GOTO 123
      IF(FCHUZZ.EQ.'A'.AND.ISYSTM.EQ.3) WRITE(*,304)
      WRITE(*,250)
      GOTO 119
C
 120  KFLAG=1
      WRITE(*,252)
      READ(*,253) FZNAME
      GOTO 129
C
 121  KFLAG=2
      WRITE(*,254)
      READ(*,253) FZNAME
      GOTO 124
C
 122  KFLAG=3
      WRITE(*,255)
      READ(*,253) FZNAME
      GOTO 124
C
 123  KFLAG=4
      WRITE(*,260)
 260  FORMAT(/,/,' ENTER ''DRIVE.FILENAME.EXT'' OF FILE TO BE ADDED'
     +,' TO  ',\)
      READ(*,253) FZNAME
      GOTO 124
C
 124  IF(KFLAG.EQ.2) THEN
        OPEN(6,FILE=FZNAME,FORM='FORMATTED',STATUS='NEW')
        IF(ISYSTM.EQ.3) THEN
          WRITE(*,304)
 304      FORMAT(/,/,/,/,1X,'SYSTEM WILL BE SIMULATED AS SINGLE ZON'
     +,'E.',/,1X,'THEREFORE; DATA FOR ONLY ONE ZONE CAN BE ENTERED '
     +,/,1X,'FOR MULTIPLE DIFFUSERS IN THE ZONE, THE AVERAGE TRUNK',
     +/,1X,'LENGTH AND LONGEST BRANCH LENGTH SHOULD BE ENTERED ',//)
```

```
          GOTO 168
        ENDIF
        WRITE(*,'(/A)')' ZONES ARE TO BE NUMBERED/DATA ENTERED IN ORDER'
        WRITE(*,*) 'OF INCREASING DISTANCE FROM SUPPLY FAN TO ZONE '
        WRITE(*,*) 'BRANCH DUCT.'
        WRITE(*,380)
 380    FORMAT(1X,'FOR MULTIPLE DIFFUSERS IN THE ZONE, THE AVERAGE '
     +,'TRUNK',/,1X,'LENGTH AND LONGEST BRANCH LENGTH SHOULD BE ',
     +'ENTERED. ',//)
C
 168    ISTEP=1
 126    WRITE(*,261) ISTEP
 261    FORMAT(/,/,/,1X,'ENTER THE DISTANCE FROM THE SUPPLY FAN TO '
     +,'THE ZONE BRANCH DUCT(FT),',/,' LENGTH OF BRANCH DUCT(FT)',/,
     +' AND AREA(SQFT) FOR ZONE',1X,I2,/,/)
        READ(*,*) L(ISTEP),LZ(ISTEP),AZ(ISTEP)
        IF(ISTEP.EQ.1) GOTO 141
        IF(L(ISTEP).LT.L(ISTEP-1)) THEN
          WRITE(*,'(/A)') ' DISTANCE FROM THE SUPPLY FAN IS TOO SHORT.'
          GOTO 126
        ENDIF
 141    WRITE(*,'(/A)') ' ENTER THE SENSIBLE LOAD(BTU/HR)'
        WRITE(*,*) 'LATENT LOAD(BTU/HR),SET POINT TEMPERATURE(oF),'
        IF(ISYSTM.EQ.2) THEN
          WRITE(*,'(A/)') ' MINIMUM AIR VOLUME RATE(CFM), AND LIGHTING E
     +NERGY(BTU/HR-SQFT) FOR. '
        ELSE
          WRITE(*,'(A/)') ' AIR VOLUME RATE(CFM), AND LIGHTING ENERGY(BT
     +U/HR-SQFT) FOR '
        ENDIF
        DO 10 J=1,24
          WRITE(*,262) ISTEP,J
 262      FORMAT(/,1X,'ZONE',1X,I2,3X,'HOUR',1X,I2)
 10     READ(*,*) QSZ(ISTEP,J),QLZ(ISTEP,J),TZ(ISTEP,J),CFMZ(ISTEP,J),QL
     +GZ(ISTEP,J)
        ISTEP=ISTEP+1
        IF(ISYSTM.EQ.3) GOTO 169
 125    WRITE(*,'(///A\)') ' ARE THERE MORE ZONES FOR DATA INPUT?(Y/N) '
        READ(*,251) YN4
        IF(YN4.NE.'Y'.AND.YN4.NE.'N') GOTO 125
        IF(YN4.EQ.'Y') GOTO 126
C
 169    DO 11 I=1,ISTEP-1
          WRITE(6,*) L(I),LZ(I),AZ(I)
          DO 12 J=1,24
 12       WRITE(6,*) QSZ(I,J),QLZ(I,J),TZ(I,J),CFMZ(I,J),QLGZ(I,J)
 11     CONTINUE
        L(ISTEP)=0.0
```

```
          LZ(ISTEP)=0.0
          AZ(ISTEP)=0.0
          WRITE(6,*) L(ISTEP),LZ(ISTEP),AZ(ISTEP)
          REWIND 6
          CLOSE(6)
          GOTO 130
C
        ELSEIF(KFLAG.EQ.3) THEN
          OPEN(6,FILE=FZNAME,FORM='FORMATTED',STATUS='OLD')
          REWIND 6
          CLOSE(6)
          GOTO 138
C
        ELSEIF(KFLAG.EQ.4) THEN
 137      OPEN(6,FILE=FZNAME,FORM='FORMATTED',STATUS='OLD')
          REWIND 6
          KSTEP=1
 133      READ(6,*) L(KSTEP),LZ(KSTEP),AZ(KSTEP)
          IF(AZ(KSTEP).EQ.0.0) THEN
            REWIND 6
            GOTO 134
          ENDIF
          DO 16 I=1,24
 16       READ(6,*) QSZ(KSTEP,J),QLZ(KSTEP,J),TZ(KSTEP,J),
     +CFMZ(KSTEP,J),QLGZ(KSTEP,J)
          KSTEP=KSTEP+1
          GOTO 133
C
 134      WRITE(*,269) KSTEP-1
 269      FORMAT(/,/,/,' CURRENTLY THERE IS DATA FOR ',I2,' ZONES IN '
     +,'THE DATA FILE ',/,/)
          WRITE(*,270)
 270      FORMAT(/,/,/,1X,'ZONE',5X,'BRANCH DISTANCE FROM SUPPLY FAN'
     +,/,/)
          DO 17 I=1,KSTEP-1
            WRITE(*,271) I,L(I)
 271        FORMAT(2X,I2,20X,F7.2)
 17       CONTINUE
          WRITE(*,'(///A)') ' REMEMBER, ZONES MUST BE NUMBERED BY '
          WRITE(*,'(A/)') ' INCREASING DISTANCE FROM THE SUPPLY FAN '
          IF((KSTEP-1).EQ.1) THEN
            DLOW=0.0
            DHIGH=L(KSTEP-1)
          ELSE
            DLOW=L(KSTEP-2)
            DHIGH=L(KSTEP-1)
          ENDIF
          WRITE(*,272) KSTEP-1,DLOW,DHIGH
```

```
272    FORMAT(' FOR EXAMPLE, THE BRANCH DUCT FOR A NEW ZONE',I3,/,
      +1X,'MUST BE BETWEEN',1X,F7.2,' FT AND',F7.2,' FEET AWAY',/,
      +1X,'FROM THE SUPPLY FAN IN THE TRUNK DUCT.',/,/,/)
135    WRITE(*,'(/A\)') ' ENTER THE NUMBER OF THE NEW ZONE.---'
       READ(*,*) NZONE
       IF(NZONE.LT.1) GOTO 135
       IF(NZONE.GT.KSTEP) NZONE=KSTEP
       WRITE(*,273) NZONE
273    FORMAT(/,/,/,' ENTER THE DISTANCE TO THE BRANCH FROM THE '
      +,'SUPPLY FAN(FT)',/,' LENGTH OF BRANCH DUCT(FT) AND AREA',
      +'(SQFT) FOR THE NEW ZONE ',I3,/)
       READ(*,*) LNEW,LZNEW,AZNEW
       IF(NZONE.GT.(KSTEP-1).AND.LNEW.GE.L(KSTEP-1)) THEN
         GOTO 142
       ELSEIF(NZONE.GT.(KSTEP-1).AND.LNEW.LT.L(KSTEP-1)) THEN
         WRITE(*,289) NZONE,L(KSTEP-1)
289      FORMAT(/,/,' FOR THE NEW ZONE TO BE NUMBERED ',I2,',',/
      +,' THE DISTANCE FROM THE SUPPLY FAN TO THE BRANCH DUCT',/,
      +,' MUST BE AT LEAST ',F7.2,1X,'FEET.',/)
         GOTO 135
       ELSEIF((NZONE.EQ.1).AND.(LNEW.GT.L(NZONE))) THEN
         LALOW=0.0
         LAHIGH=L(NZONE)
         WRITE(*,276) NZONE,LALOW,LAHIGH
         GOTO 135
       ELSEIF(NZONE.EQ.1) THEN
         GOTO 142
       ELSEIF(LNEW.LT.L(NZONE-1).OR.LNEW.GT.L(NZONE)) THEN
         WRITE(*,276) NZONE,L(NZONE-1),L(NZONE)
276      FORMAT(/,/,' FOR THE NEW ZONE TO BE NUMBERED ',I2,',',/
      +,' THE DISTANCE FROM THE SUPPLY FAN TO THE BRANCH DUCT',/,
      +' MUST BE BETWEEN',1X,F7.2,1X,'AND ',F7.2,1X,'FEET.')
         GOTO 135
       ENDIF
142    CONTINUE
       KS=1
       DO 18 I=NZONE,KSTEP
         L(KSTEP+2-KS)=L(KSTEP+1-KS)
         LZ(KSTEP+2-KS)=LZ(KSTEP+1-KS)
         AZ(KSTEP+2-KS)=AZ(KSTEP+1-KS)
         IF(KS.EQ.1) GOTO 18
         DO 19 J=1,24
           QSZ(KSTEP+2-KS,J)=QSZ(KSTEP+1-KS,J)
           QLZ(KSTEP+2-KS,J)=QLZ(KSTEP+1-KS,J)
           TZ(KSTEP+2-KS,J)=TZ(KSTEP+1-KS,J)
           CFMZ(KSTEP+2-KS,J)=CFMZ(KSTEP+1-KS,J)
19       QLGZ(KSTEP+2-KS,J)=QLGZ(KSTEP+1-KS,J)
18     KS=KS+1
```

```
C
      L(NZONE)=LNEW
      LZ(NZONE)=LZNEW
      AZ(NZONE)=AZNEW
C
      IF(ISYSTM.EQ.2) THEN
        WRITE(*,306) NZONE
 306    FORMAT(/,/,1X,'ENTER THE SENSIBLE LOAD(BTU/HR),',/,1X,
     +'LATENT LOAD(BTU/HR),SET POINT TEMPERATURE(oF),',/,1X,
     +'MINIMUM AIR VOLUME RATE(CFM) AND LIGHTING ENERGY(BTU/HR-SQFT)',
     +/,1X,'FOR ZONE',1X,I2,/)
      ELSE
        WRITE(*,274) NZONE
 274    FORMAT(/,/,1X,'ENTER THE SENSIBLE LOAD(BTU/HR),',/,1X,
     +'LATENT LOAD(BTU/HR), SET POINT TEMPERATURE(oF),',/,1X,
     +'AIR VOLUME RATE(CFM) AND LIGHTING ENERGY(BTU/HR-SQFT)',/,1X,
     +'FOR ZONE',1X,I2,/)
      ENDIF
      DO 20 J=1,24
        WRITE(*,275) J
 275    FORMAT(/,1X,'HOUR',1X,I3)
 20   READ(*,*) QSZ(NZONE,J),QLZ(NZONE,J),TZ(NZONE,J),CFMZ(NZONE,J)
     +,QLGZ(NZONE,J)
C
      DO 21 I=1,KSTEP+1
        WRITE(6,*) L(I),LZ(I),AZ(I)
        IF(I.EQ.KSTEP+1) GOTO 21
        DO 22 J=1,24
 22     WRITE(6,*) QSZ(I,J),QLZ(I,J),TZ(I,J),CFMZ(I,J),QLGZ(I,J)
 21   CONTINUE
      REWIND 6
      CLOSE(6)
C
 136  WRITE(*,'(/A\)') ' DO YOU WANT TO ADD ANOTHER ZONE?(Y/N) '
      READ(*,'(A1)') YN6
      IF(YN6.NE.'Y'.AND.YN6.NE.'N') GOTO 136
      IF(YN6.EQ.'Y') GOTO 137
      GOTO 130
     ENDIF
C
 130 WRITE(*,'(/A\)') ' DO YOU WANT TO EDIT THIS DATA?(Y/N) '
     READ(*,251) YN5
     IF(YN5.NE.'Y'.AND.YN5.NE.'N') GOTO 130
     IF(YN5.EQ.'Y') GOTO 129
     GOTO 138
C
 129  OPEN(6,FILE=FZNAME,FORM='FORMATTED',STATUS='OLD')
      REWIND 6
```

```
      JSTEP=1
127   READ(6,*) L(JSTEP),LZ(JSTEP),AZ(JSTEP)
      IF(AZ(JSTEP).EQ.0.0) THEN
        REWIND 6
        GOTO 128
      ENDIF
      DO 13 J=1,24
13    READ(6,*) QSZ(JSTEP,J),QLZ(JSTEP,J),TZ(JSTEP,J),CFMZ(JSTEP,J),QL
     +GZ(JSTEP,J)
      JSTEP=JSTEP+1
      GOTO 127
C
128   IF(ISYSTM.EQ.3) THEN
        WRITE(*,'(/A\)')' ENTER "1"; OR IF EDITTING IS COMPLETE "99" '
        GOTO 170
      ELSE
        WRITE(*,'(/A)')' ENTER THE ZONE FOR WHICH DATA IS TO BE '
        WRITE(*,'(A\)')' EDITTED OR "99" IF EDITTING IS COMPLETE. '
      ENDIF
170   READ(*,*) IZ
      IF(IZ.EQ.99) GOTO 132
      IF(((IZ.LT.1).OR.(IZ.GT.(JSTEP-1)).OR.((ISYSTM.EQ.3).AND.
     +(IZ.GT.1))) THEN
        WRITE(*,263) IZ
263     FORMAT(/,/,/,' NO DATA EXISTS FOR ZONE',I3,'. TRY ANOTHER'
     +,' ZONE ',/,/)
        GOTO 128
      ENDIF
131   WRITE(*,264) IZ
264   FORMAT(/,/,' ENTER THE HOUR WHICH DATA IS TO BE EDITTED IN '
     +,'ZONE ',I2,' ')
      WRITE(*,'(A\)') ' IF DATA IS NOT HOURLY DATA(ie. DUCT LENGTHS OR
     + AREA), TYPE "0".  '
      READ(*,*) JZ
      IF(JZ.LT.0.OR.JZ.GT.24) THEN
        WRITE(*,250)
        GOTO 131
      ELSEIF(JZ.EQ.0) THEN
        WRITE(*,265) IZ,L(IZ),LZ(IZ),AZ(IZ)
265     FORMAT(/,/,/,' EXISTING DATA FOR ZONE',I3,/,/,
     +3X,'DISTANCE FROM SUPPLY FAN TO BRANCH DUCT(FT)',10X,F8.2,/,
     +3X,'LENGTH OF BRANCH DUCT(FT)',28X,F8.2,/,
     +3X,'AREA(SQFT)',43X,F8.2)
196     WRITE(*,266) IZ
266     FORMAT(/,/,/,1X,'ENTER NEW DATA FOR ZONE',I3,'---',\)
        READ(*,*) LEDIT,LZEDIT,AZEDIT
        IF(LEDIT.LT.0.0.OR.LZEDIT.LT.0.0.OR.AZEDIT.LT.0.0) THEN
          WRITE(*,*) '  NEGATIVE LENGTHS/AREAS NOT ALLOWED '
```

```
          GOTO 196
         ENDIF
         IF((JSTEP.EQ.2).OR.(ISYSTM.EQ.3).OR.((IZ.EQ.(JSTEP-1))
     +.AND.(LEDIT.GE.L(JSTEP-2))).OR.((IZ.EQ.1).AND.(LEDIT.LE.
     +L(2)))) THEN
          L(IZ)=LEDIT
          LZ(IZ)=LZEDIT
          AZ(IZ)=AZEDIT
          GOTO 128
         ELSEIF((IZ.EQ.(JSTEP-1)).AND.(LEDIT.LT.L(IZ-1))) THEN
          LLOW=L(IZ-1)
          WRITE(*,375) IZ,LLOW
          GOTO 131
         ELSEIF((IZ.EQ.1).AND.(LEDIT.GT.L(IZ+1))) THEN
          LLOW=0.0
          LHIGH=L(IZ+1)
          WRITE(*,374) IZ,LLOW,LHIGH
          GOTO 131
         ELSEIF((LEDIT.GT.L(IZ+1)).OR.(LEDIT.LT.L(IZ-1))) THEN
          LLOW=L(IZ-1)
          LHIGH=L(IZ+1)
          WRITE(*,374) IZ,LLOW,LHIGH
          GOTO 131
         ELSE
          L(IZ)=LEDIT
          LZ(IZ)=LZEDIT
          AZ(IZ)=AZEDIT
          GOTO 128
         ENDIF
 374      FORMAT(//,1X,'THE TRUNK DUCT LENGTH FOR ZONE',1X,I2,
     +1X,'MUST BE BETWEEN',/,1X,F6.1,1X,'AND',1X,F6.1,1X,'FEET.',//)
 375      FORMAT(//,1X,'THE TRUNK DUCT LENGTH FOR ZONE',1X,I2,
     +1X,'MUST BE GREATER',/,1X,'THAN',1X,F6.1,1X,'FEET.',//)
        ENDIF
C
        WRITE(*,267) IZ,JZ,QSZ(IZ,JZ),QLZ(IZ,JZ),TZ(IZ,JZ),CFMZ(IZ,JZ),Q
     +LGZ(IZ,JZ)
 267    FORMAT(/,/,/,' EXISTING DATA FOR ZONE',I3,' HOUR',I3,/,/,
     +3X,'SENSIBLE LOAD(BTU/HR)',7X,F12.4,/,
     +3X,'LATENT LOAD(BTU/HR)',9X,F12.4,/,
     +3X,'SETPOINT TEMPERATURE(oF)',4X,F12.4,/,
     +3X,'AIR VOLUME RATE(CFM)',8X,F12.4,/,
     +3X,'LIGHTING ENERGY(BTU/HR-SQFT)',F12.4,/)
        WRITE(*,268) IZ,JZ
 268    FORMAT(/,/,1X,'ENTER NEW DATA FOR ZONE',I3,' HOUR',I3,'---',
     +\)
        READ(*,*)QSZ(IZ,JZ),QLZ(IZ,JZ),TZ(IZ,JZ),CFMZ(IZ,JZ),QLGZ(IZ,JZ)
        GOTO 128
```

```
C
 132    DO 14 I=1,JSTEP
          WRITE(6,*) L(I),LZ(I),AZ(I)
          IF(I.EQ.JSTEP) GOTO 14
          DO 15 J=1,24
 15       WRITE(6,*) QSZ(I,J),QLZ(I,J),TZ(I,J),CFMZ(I,J),QLGZ(I,J)
 14     CONTINUE
        REWIND 6
        CLOSE(6)
C
 138  CONTINUE
      OPEN(7,FILE=FNAME,FORM='FORMATTED',STATUS='OLD')
      DO 23 J=1,24
 23   READ(7,*) TOA(J),TWB(J),QPLW(J),RH(J)
      REWIND 7
      CLOSE(7)
C
      OPEN(6,FILE=FZNAME,FORM='FORMATTED',STATUS='OLD')
      MSTEP=1
 139  READ(6,*) L(MSTEP),LZ(MSTEP),AZ(MSTEP)
      IF((AZ(MSTEP).EQ.0.0).OR.((ISYSTM.EQ.3).AND.(MSTEP.EQ.2))) THEN
        REWIND 6
        CLOSE(6)
        GOTO 140
      ENDIF
      DO 24 J=1,24
      READ(6,*) QSZ(MSTEP,J),QLZ(MSTEP,J),TZ(MSTEP,J),CFMZ(MSTEP,J),
     +QLGZ(MSTEP,J)
      IF(ISYSTM.EQ.2) CFMZMN(MSTEP,J)=CFMZ(MSTEP,J)
 24   CONTINUE
      MSTEP=MSTEP+1
      GOTO 139
 140  CONTINUE
C
C=========SETS THE NUMBER OF ZONES IN SIMULATION===================
C
      N=MSTEP-1
C
C=========INPUT OF MAXIMUM ZONE PRIMARY AND INDUCED CFM'S===========
C=========(USED FOR VAV SYSTEM ONLY)==============================
C
      IF(ISYSTM.EQ.2) THEN
 171    WRITE(*,307)
 307    FORMAT(/,/,/,/,/,/,1X,'THE NEXT INPUTS WILL BE FOR MAXIMUM',
     +' ALLOWABLE',/,1X,'ZONE AND ZONE INDUCTOR AIR VOLUME RATES',
     +'(CFM).',/,/,5X,'NOTE: IF THE MAXIMUM INDUCTOR CFM IS NOT ',
     +'KNOWN,',/,5X,'ENTER A VALUE EQUAL TO 75% OF THE MAXIMUM ',
     +'ZONE CFM.',/,/)
```

```
C
      WRITE(*,377) N,N
 377  FORMAT(//,1X,'IF YOU CHOOSE THE EDIT OR USE OPTION BELOW,'
     +,1X,'THE',/,1X,'PROGRAM WILL EXPECT TO READ DATA FOR ',I2,
     +1X,'ZONES FROM',/,1X,'THE EXISTING FILE.',/,1X,'IF YOU',1X,
     +'CHOOSE THE CREATE OPTION BELOW, THE',/,1X,'PROGRAM WILL ',
     +'ONLY READ INPUT FOR ',I2,1X,'ZONES.',//)
C
      WRITE(*,288)
      WRITE(*,376)
 376  FORMAT(/,1X,'ADD ADDITIONAL ZONES TO AN EXISTING ',
     +'FILE?(TYPE A)  ',\)
C
      READ(*,251) FCHUZM
      IF(FCHUZM.EQ.'E') GOTO 172
      IF(FCHUZM.EQ.'C') GOTO 173
      IF(FCHUZM.EQ.'U') GOTO 174
      IF(FCHUZM.EQ.'A') GOTO 199
      WRITE(*,250)
      GOTO 171
C
 172  OFLAG=1
      WRITE(*,252)
      READ(*,253) MAXCFM
      GOTO 175
C
 173  OFLAG=2
      WRITE(*,254)
      READ(*,253) MAXCFM
      GOTO 175
C
 174  OFLAG=3
      WRITE(*,255)
      READ(*,253) MAXCFM
      GOTO 175
C
 199  OFLAG=4
      WRITE(*,260)
      READ(*,253) MAXCFM
C
 175  IF(OFLAG.EQ.2) THEN
        OPEN(8,FILE=MAXCFM,FORM='FORMATTED',STATUS='NEW')
        WRITE(*,308)
 308    FORMAT(/,/,/,1X,'ENTER THE MAXIMUM ZONE AIR VOLUME RATE',
     +'(CFM)',/,1X,'AND THE MAXIMUM ZONE INDUCTOR AIR VOLUME ',/,1X,
     +'RATE(CFM) FOR.')
        DO 28 I=1,N
          WRITE(*,309) I
```

```
 309        FORMAT(/,4X,'ZONE',1X,I2,/)
            READ(*,*) CFMZMX(I),CFMZIM(I)
 28       WRITE(8,*) CFMZMX(I),CFMZIM(I)
          REWIND 8
          CLOSE(8)
          GOTO 176
C
        ELSEIF(OFLAG.EQ.4) THEN
          WRITE(*,382) MAXCFM,N
 382      FORMAT(1X,'ENTER THE NUMBER OF ZONES OF DATA ALREADY',/,
     +1X,'CONTAINED WITHIN FILE',3X,A14,/,1X,'NOTE: THE PROGRAM ',
     +'WILL EXPECT A TOTAL OF ',I2,' ZONES',/,1X,'OF DATA WHEN ',
     +'APPENDING IS COMPLETED.  ',\)
          READ(*,*) KAPP
          OPEN(8,FILE=MAXCFM,FORM='FORMATTED',STATUS='OLD')
 202      DO 39 I=1,KAPP
 39       READ(8,*) CFMZMX(I),CFMZIM(I)
          REWIND 8
C
 201      WRITE(*,378) N
 378      FORMAT(//,1X,'ENTER THE NUMBER OF THE NEW ZONE.',/,
     +1X,'IT MUST BE NUMBERED BETWEEN 1 AND ',I2,1X,'.  ',\)
          READ(*,*) INWZNE
          IF((INWZNE.LT.1).OR.(INWZNE.GT.N)) GOTO 201
          IS=1
          DO 40 I=INWZNE,KAPP
            CFMZMX(KAPP+2-IS)=CFMZMX(KAPP+1-IS)
            CFMZIM(KAPP+2-IS)=CFMZIM(KAPP+1-IS)
 40       IS=IS+1
          WRITE(*,379) INWZNE
 379      FORMAT(//,1X,'ENTER THE MAXIMUM ZONE AIR VOLUME RATE',
     +'(CFM)',/,1X,'AND THE MAXIMUM ZONE INDUCTOR AIR VOLUME ',
     +/,1X,'RATE(CFM) FOR ZONE ',I2,'.  ',\)
          READ(*,*) CFMZMX(INWZNE),CFMZIM(INWZNE)
          DO 41 I=1,N
 41       WRITE(8,*) CFMZMX(I),CFMZIM(I)
          REWIND 8
          KAPP=KAPP+1
          IF(KAPP.LT.N) GOTO 202
          CLOSE(8)
          GOTO 176
C
        ELSEIF(OFLAG.EQ.3) THEN
          OPEN(8,FILE=MAXCFM,FORM='FORMATTED',STATUS='OLD')
          REWIND 8
          CLOSE(8)
          GOTO 178
C
```

```
        ELSEIF(OFLAG.EQ.1) THEN
          GOTO 177
        ENDIF
C
 176    WRITE(*,'(/A\)') ' DO YOU WANT TO EDIT THIS DATA(Y/N)? '
        READ(*,251) YN1
        IF(YN1.NE.'Y'.AND.YN1.NE.'N') GOTO 176
        IF(YN1.EQ.'Y') GOTO 177
        GOTO 178
C
 177    OPEN(8,FILE=MAXCFM,FORM='FORMATTED',STATUS='OLD')
        REWIND 8
 179    WRITE(*,310) N
 310    FORMAT(/,/,/,1X,'ENTER THE ZONE FOR WHICH DATA IS TO BE ',
     +'EDITTED',/,1X,'(i.e. ZONES 1 THROUGH',1X,I2,'), OR "0" IF ',
     +'EDITTING',/,1X,'IS COMPLETE.  ',\)
        READ(*,*) IZN
        IF(IZN.EQ.0) THEN
          CLOSE(8)
          GOTO 178
        ELSEIF(IZN.LT.1.OR.IZN.GT.N) THEN
          WRITE(*,250)
          GOTO 179
        ENDIF
C
        DO 29 I=1,N
 29     READ(8,*) CFMZMX(I),CFMZIM(I)
        REWIND 8
        WRITE(*,311) IZN,CFMZMX(IZN),CFMZIM(IZN)
 311    FORMAT(/,/,/,/,1X,'EXISTING DATA FOR ZONE',1X,I2,/,/,
     +5X,'MAXIMUM ZONE AIR VOLUME RATE(CFM)',11X,F8.2,/,
     +5X,'MAXIMUM ZONE INDUCTOR AIR VOLUME RATE(CFM)',2X,F8.2,/,/)
        WRITE(*,312) IZN
 312    FORMAT(/,1X,'ENTER THE NEW DATA FOR ZONE',1X,I2,2X,\)
        READ(*,*) CFMZMX(IZN),CFMZIM(IZN)
        DO 30 I=1,N
 30     WRITE(8,*) CFMZMX(I),CFMZIM(I)
        CLOSE(8)
        GOTO 177
      ENDIF
C
 178  CONTINUE
C
      IF(ISYSTM.EQ.2) THEN
        OPEN(8,FILE=MAXCFM,FORM='FORMATTED',STATUS='OLD')
        DO 31 I=1,N
 31     READ(8,*) CFMZMX(I),CFMZIM(I)
        REWIND 8
```

```
        CLOSE(8)
      ENDIF
C
C==========INPUT OF FAN DATA=====================================
C=========(ALLOWS FOR FAN MOTORS TO BE IN OR OUT OF AIRSTREAM)======
C
      WRITE(*,'(///A)') ' '
 101  WRITE(*,'(/A\)')' IS THE SUPPLY FAN MOTOR IN THE AIRSTREAM?(Y/N) '
      READ(*,'(A1)') YN1
      IF(YN1.NE.'Y' .AND. YN1.NE.'N') GOTO 101
      IF(YN1.EQ.'Y') THEN
        WRITE(*,*) 'ENTER THE DESIGN EFFICIENCY OF THE MOTOR.'
        WRITE(*,'(A\)') ' (0.0-1.0)  '
        READ(*,*) SMOTn
      ELSE
        SMOTn=1.0
      ENDIF
      WRITE(*,*) 'ENTER THE DESIGN EFFICIENCY OF THE FAN.'
      WRITE(*,'(A\)') ' (0.0-1.0)  '
      READ(*,*) SFANn
      WRITE(*,*) 'ENTER THE DESIGN TOTAL PRESSURE DROP IN'
      WRITE(*,'(A\)') ' THE SUPPLY DUCT.(INCHES OF WATER)  '
      READ(*,*) TPS
C
C==========ALLOWS FOR AN OPTION ON THE USE OF A RETURN FAN===========
C
 102  WRITE(*,'(///A\)') ' IS A RETURN FAN TO BE USED?(Y/N) '
      READ(*,'(A1)') YN2
      IF(YN2.NE.'Y'.AND.YN2.NE.'N') GOTO 102
      IF(YN2.EQ.'N') THEN
        RMOTn=1.0
        RFANn=1.0
        TPR=0.0
      ELSE
 166    WRITE(*,'(/A\)') ' IS THE RETURN FAN MOTOR IN THE AIRSTREAM?(Y/N
     +) '
        READ(*,'(A1)') YN3
        IF(YN3.NE.'Y'.AND.YN3.NE.'N') GOTO 166
        IF(YN3.EQ.'Y') THEN
          WRITE(*,*) 'ENTER THE DESIGN EFFICIENCY OF THE MOTOR.'
          WRITE(*,'(A\)') ' (0.0-1.0)  '
          READ(*,*) RMOTn
        ELSE
          RMOTn=1.0
        ENDIF
        WRITE(*,*) 'ENTER THE DESIGN EFFICIENCY OF THE FAN.'
        WRITE(*,'(A\)') ' (0.0-1.0)  '
        READ(*,*) RFANn
```

```
      WRITE(*,*) 'ENTER THE DESIGN TOTAL PRESSURE DROP IN'
      WRITE(*,'(A\)') ' RETURN (INCHES OF WATER)  '
      READ(*,*) TPP
     ENDIF
C
C=========FAN CONTROL METHOD CHOICE================================
C=========(NOT FOR USE WITH THE TERMINAL REHEAT SYSTEM)============
C
     IF(ISYSTM.NE.1) THEN
      IF(ISYSTM.EQ.3) THEN
       ISFAN=4
       GOTO 194
      ENDIF
      WRITE(*,335)
 335  FORMAT(/,/,/,/,/,' ENTER THE METHOD TO BE USED FOR SUPPLY',
    +1X,'VOLUME',/,1X,'CONTROL BY SELECTING THE NUMBER TO THE LEFT'
    +,1X,'OF',/,1X,'THE METHOD DESIRED.',/,/,
    +5X,'(1)  VARIABLE SPEED MOTOR',/,
    +5X,'(2)  INLET DAMPERS',/,
    +5X,'(3)  DISCHARGE DAMPERS',/,
    +5X,'(4)  CYCLING FAN',/,/)
C
 186  WRITE(*,'(A\)') ' YOUR CHOICE?(1/2/3/4)  '
      READ(*,*) ISFAN
C
C=========CURVE FIT DATA COEFFICIENTS FOR SUPPLY FAN CONTROL========
C=========(OBTAINED FROM DOE 2.1B ENGINEERS MANUAL)================
C
 194  IF(ISFAN.LT.1.OR.ISFAN.GT.4) THEN
       WRITE(*,250)
       WRITE(*,335)
       GOTO 186
      ELSEIF(ISFAN.EQ.1) THEN
       SFPLD(1)=0.00153028
       SFPLD(2)=0.00520806
       SFPLD(3)=1.1086242
       SFPLD(4)=-0.11635563
      ELSEIF(ISFAN.EQ.2) THEN
       SFPLD(1)=0.35071223
       SFPLD(2)=0.3080535
       SFPLD(3)=-0.5413736
       SFPLD(4)=0.87198823
      ELSEIF(ISFAN.EQ.3) THEN
       SFPLD(1)=0.37073425
       SFPLD(2)=0.97250253
       SFPLD(3)=-0.3424076
       SFPLD(4)=0.0
      ELSEIF(ISFAN.EQ.4) THEN
```

```
          SFPLD(1)=0.0
          SFPLD(2)=1.0
          SFPLD(3)=0.0
          SFPLD(4)=0.0
        ENDIF
C
C==========OPTION TO CHANGE SUPPLY FAN DEFAULT COEFFICIENTS==========
C
 187    WRITE(*,339) SFPLD(1),SFPLD(2),SFPLD(3),SFPLD(4)
 339    FORMAT(/,/,/,/,/,' THE TEMPERATURE RISE IN THE SUPPLY DUCT',
     +1X,'DUE TO THE',/,1X,'FAN/FAN & MOTOR WILL BE CALCULATED AS',
     +1X,'FOLLOWS:',/,/,5X,'DELTA TEMP=(DELTA TEMP DESIGN)*(POLY)/',
     +'PLD',/,/,10X,'WHERE  PLD=ACTUAL CFM/DESIGN CFM',/,17X,
     +'POLY=A+B*PLD+C*(PLD**2)+D*(PLD**3)',/,/,22X,'A=',F10.8,/,
     +22X,'B=',F10.8,/,22X,'C=',F10.8,/,22X,'D=',F10.8,/,/,1X,
     +'COEFFICIENT SOURCE: DOE 2.1B ENGINEERS MANUAL-MAY 1981',//)
        WRITE(*,343)
 343    FORMAT(1X,'IF ANY OF THE CONSTANTS (i.e. A,B,C,D) NEED TO',
     +/,1X,'BE CHANGED, TYPE THE LETTER OF THE CONSTANT; IF THEY',/,
     +1X,'ARE ALL OKAY, TYPE "E"')
        WRITE(*,'(A\)') ' YOUR CHOICE?(A/B/C/D/E)  '
        READ(*,'(A1)') ICT
        IF(ICT.EQ.'E') THEN
          GOTO 188
        ELSEIF(ICT.EQ.'A') THEN
          WRITE(*,'(A\)') ' ENTER THE NEW CONSTANT. A='
          READ(*,*) SFPLD(1)
        ELSEIF(ICT.EQ.'B') THEN
          WRITE(*,'(A\)') ' ENTER THE NEW CONSTANT. B='
          READ(*,*) SFPLD(2)
        ELSEIF(ICT.EQ.'C') THEN
          WRITE(*,'(A\)') ' ENTER THE NEW CONSTANT. C='
          READ(*,*) SFPLD(3)
        ELSEIF(ICT.EQ.'D') THEN
          WRITE(*,'(A\)') ' ENTER THE NEW CONSTANT. D='
          READ(*,*) SFPLD(4)
        ELSE
          WRITE(*,250)
        ENDIF
        GOTO 187
 188    CONTINUE
        IF(YN2.EQ.'N') GOTO 189
        IF(ISYSTM.EQ.3) THEN
          IRFAN=4
          GOTO 195
        ENDIF
        WRITE(*,344)
 344    FORMAT(/,/,/,/,/,' ENTER THE METHOD TO BE USED FOR RETURN',
```

```
     +1X,'VOLUME',/,1X,'CONTROL BY SELECTING THE NUMBER TO THE LEFT'
     +,1X,'OF',/,1X,'THE METHOD DESIRED.',/,/,
     +5X,'(1)  VARIABLE SPEED MOTOR',/,
     +5X,'(2)  INLET DAMPERS',/,
     +5X,'(3)  DISCHARGE DAMPERS',/,
     +5X,'(4)  CYCLING FAN',/,/)
C
 190    WRITE(*,'(A\)') ' YOUR CHOICE?(1/2/3/4)  '
        READ(*,*) IRFAN
C
C=========CURVE FIT DATA COEFFICIENTS FOR RETURN FAN CONTROL========
C=========(OBTAINED FROM DOE 2.1B ENGINEERS MANUAL)================
C
 195    IF(IRFAN.LT.1.OR.IRFAN.GT.4) THEN
          WRITE(*,250)
          WRITE(*,344)
          GOTO 190
        ELSEIF(IRFAN.EQ.1) THEN
          RFPLD(1)=0.00153028
          RFPLD(2)=0.00520806
          RFPLD(3)=1.1086242
          RFPLD(4)=-0.11635563
        ELSEIF(IRFAN.EQ.2) THEN
          RFPLD(1)=0.35071223
          RFPLD(2)=0.3080535
          RFPLD(3)=-0.5413736
          RFPLD(4)=0.87198823
        ELSEIF(IRFAN.EQ.3) THEN
          RFPLD(1)=0.37073425
          RFPLD(2)=0.97250253
          RFPLD(3)=-0.3424076
          RFPLD(4)=0.0
        ELSEIF(IRFAN.EQ.4) THEN
          RFPLD(1)=0.0
          RFPLD(2)=1.0
          RFPLD(3)=0.0
          RFPLD(4)=0.0
        ENDIF
C
C=========OPTION TO CHANGE RETURN FAN DEFAULT COEFFICIENTS==========
C
 191    WRITE(*,345) RFPLD(1),RFPLD(2),RFPLD(3),RFPLD(4)
 345    FORMAT(/,/,/,/,/,' THE TEMPERATURE RISE IN THE RETURN DUCT',
     +1X,'DUE TO THE',/,1X,'FAN/FAN & MOTOR WILL BE CALCULATED AS',
     +1X,'FOLLOWS.',/,/,5X,'DELTA TEMP=(DELTA TEMP DESIGN)*(POLY)/',
     +'PLD',/,/,10X,'WHERE  PLD=ACTUAL CFM/DESIGN CFM',/,17X,
     +'POLY=A+B*PLD+C*(PLD**2)+D*(PLD**3)',/,/,22X,'A=',F10.8,/,
     +22X,'B=',F10.8,/,22X,'C=',F10.8,/,22X,'D=',F10.8,/,/,1X,
```

```
     +'COEFFICIENT SOURCE: DOE 2.1B ENGINEERS MANUAL-MAY 1981',//)
       WRITE(*,346)
346    FORMAT(1X,'IF ANY OF THE CONSTANTS (i.e. A,B,C,D) NEED TO',
     +/,1X,'BE CHANGED, TYPE THE LETTER OF THE CONSTANT; IF THEY',/,
     +1X,'ARE ALL OKAY, TYPE "E"')
       WRITE(*,'(A\)') ' YOUR CHOICE?(A/B/C/D/E)  '
       READ(*,'(A1)') ICT
       IF(ICT.EQ.'E') THEN
         GOTO 192
       ELSEIF(ICT.EQ.'A') THEN
         WRITE(*,'(A\)') ' ENTER THE NEW CONSTANT. A='
         READ(*,*) SFPLD(1)
       ELSEIF(ICT.EQ.'B') THEN
         WRITE(*,'(A\)') ' ENTER THE NEW CONSTANT. B='
         READ(*,*) SFPLD(2)
       ELSEIF(ICT.EQ.'C') THEN
         WRITE(*,'(A\)') ' ENTER THE NEW CONSTANT. C='
         READ(*,*) SFPLD(3)
       ELSEIF(ICT.EQ.'D') THEN
         WRITE(*,'(A\)') ' ENTER THE NEW CONSTANT. D='
         READ(*,*) SFPLD(4)
       ELSE
         WRITE(*,250)
       ENDIF
       GOTO 191
192    CONTINUE
189    CONTINUE
      ENDIF
C
      IFLAG4=0
C
C=========CALCULATES DUCT AREA***AREA=AIR FLOW/VELOCITY***==========
C
      DO 38 I=1,N
        IF(ISYSTM.EQ.2) THEN
          ACFMZ(I)=CFMZMX(I)
        ELSE
          ACFMZ(I)=CFMZ(I,12)
        ENDIF
38    ADZ(I)=ACFMZ(I)/VD
C
      DO 36 I=1,N
        IR=N+1-I
        ACFMM=0.0
        DO 37 K=1,I
          JR=N+1-K
37      ACFMM=ACFMM+ACFMZ(JR)
        ACFM(IR)=ACFMM
```

```
 36   AD(IR)=ACFM(IR)/V
C
C=========TWENTY-FOUR HOUR SIMULATION LOOP=========================
C
      DO 25 J=1,24
C
C=========INITIALIZES HOURLY SIMULATIONS===========================
C
        DO 26 I=1,N
          IFLAG8(I)=0
          QRHZ(I,J)=0.0
 26       CFMZI(I,J)=0.0
        IF(IFLAG4.EQ.1) GOTO 25
        IFLAG1=0
        IFLAG2=0
        IFLAG3=0
        IFLAG7=0
        IFLAG9=0
        IWCHK=0
        IF(J.EQ.1) TPL=TPLA
        JX=J
C
        IF((ISYSTM.EQ.3).AND.(ICNTRL.NE.2)) THEN
          FRHRA=0.8
        ELSE
          FRHRA=1.0
        ENDIF
C
C=========SETS VAV ZONE AIR FLOWS TO MAXIMUMS FOR INITIAL ITERATION=
C
        CFMX=0.
        DO 5 I=1,N
          IF(ISYSTM.EQ.2.AND.QSZ(I,JX).NE.0.0) CFMZ(I,JX)=CFMZMX(I)
 5      CFMX=CFMX+CFMZ(I,J)
        CFM(1,J)=CFMX
C
 100    CALL HUMID
        CALL TDUCT
        CALL QDUCTT
        CALL TPLENUM
        CALL TSZREQD
C
        IF(ISYSTM.EQ.2) CALL CFMREQD
        IF((ISYSTM.EQ.2).AND.(IFLAG5.EQ.0)) GOTO 100
C
        IF((IFLAG2.EQ.1).AND.(IFLAG9.EQ.0)) GOTO 106
        CALL SETTLCC
        IF(IFLAG9.EQ.1) GOTO 100
```

```
      IF(IFLAG4.EQ.1) GOTO 25
      GOTO 100
 106  CONTINUE
C
C=========ITERATION ON PLENUM TEMPERATURE (TO WITHIN 0.1%((0.1oF))==
C
      D=ABS((TPL-TPL1)/TPL)
      IF (D .GT. 0.001) THEN
        IF(CFM(1,J).EQ.0.0) THEN
          TPL=TPL1
        ELSE
          TPL=(TPL+TPL1)/2.0
          IFLAG2=0
          GOTO 100
        ENDIF
      ELSE
        TPL=TPL1
      ENDIF
C
C=========CALLS FOR CALCULATION OF COIL LOADS======================
C
      CALL QRHEAT
      CALL QCCOIL
 25   CONTINUE
      IF(IFLAG4.EQ.1) GOTO 144
C
C=========FILE STORAGE OF INPUT/OUTPUT AND PRINTING OPTIONS=========
C
      WRITE(*,319)
 319  FORMAT(/,/,/,/,/,/,/,/,/,/,1X,'ENTER ''DRIVE.FILENAME.EXT ''IN',
     +' WHICH THE INPUT/',/,1X,'OUTPUT DATA IS TO BE STORED.  ',\)
      READ(*,253) OUTFILE
 185  WRITE(*,'(/A\)')' DO YOU WANT A HARD COPY OF THE OUTPUT(Y/N)? '
      READ(*,'(A1)') YN1
      IF(YN1.NE.'Y'.AND.YN1.NE.'N') GOTO 185
 193  WRITE(*,'(/A\)')' DO YOU WANT A HARD COPY OF THE INPUT(Y/N)? '
      READ(*,'(A1)') YN6
      IF(YN6.NE.'Y'.AND.YN6.NE.'N') GOTO 193
      IF(YN1.EQ.'Y'.OR.YN6.EQ.'Y') OPEN(10,FILE='LPT1')
      OPEN(9,FILE=OUTFILE,FORM='FORMATTED',STATUS='NEW')
      WRITE(*,359)
      WRITE(9,359)
      IF(YN6.EQ.'Y') WRITE(10,278)
 359  FORMAT(29X,'INPUT DATA',/,28X,12('='),/)
 278  FORMAT('1',29X,'INPUT DATA',/,29X,12('='),/)
      WRITE(*,305)
      WRITE(9,305)
      IF(YN6.EQ.'Y') WRITE(10,305)
```

```
305  FORMAT(1X,'(1) SYSTEM USED',27('.'),1X,\)
     IF(ISYSTM.EQ.1) THEN
       WRITE(*,342)
       WRITE(9,342)
       IF(YN6.EQ.'Y') WRITE(10,342)
342    FORMAT('TERMINAL REHEAT')
     ELSEIF(ISYSTM.EQ.2) THEN
       WRITE(*,348)
       WRITE(9,348)
       IF(YN6.EQ.'Y') WRITE(10,348)
348    FORMAT('VARIABLE AIR VOLUME WITH',/,44X,'INDUCTION ',
    +'REHEATERS')
     ELSE
       WRITE(*,349)
       WRITE(9,349)
       IF(YN6.EQ.'Y') WRITE(10,349)
349    FORMAT('CYCLING SYSTEM')
     ENDIF
     IF(ICNTRL.EQ.1) THEN
       WRITE(*,350) TLCCF
       WRITE(9,350) TLCCF
       IF(YN6.EQ.'Y') WRITE(10,350) TLCCF
350    FORMAT(1X,'(2) CONTROL METHOD USED',19('.'),1X,'FIXED SET ',
    +'POINT(',F4.1,'oF)')
     ELSEIF(ICNTRL.EQ.2) THEN
       WRITE(*,351)
       WRITE(9,351)
       IF(YN6.EQ.'Y') WRITE(10,351)
351    FORMAT(1X,'(2) CONTROL METHOD USED',19('.'),1X,'ZONE CONTROLLED'
    +)
     ELSE
       WRITE(*,352) SCHDLE
       WRITE(9,352) SCHDLE
       IF(YN6.EQ.'Y') WRITE(10,352) SCHDLE
352    FORMAT(1X,'(2) CONTROL METHOD USED',19('.'),1X,'OUTSIDE AIR'
    +,'CONTROLLED',/,5X,'(2a) Schedule file name',15('.'),1X,A14)
     ENDIF
     IF(IMOA.EQ.1) THEN
       WRITE(*,353)
       WRITE(9,353)
       IF(YN6.EQ.'Y') WRITE(10,353)
353    FORMAT(1X,'(3) ECONOMIZER METHOD',21('.'),1X,'NONE USED')
     ELSEIF(IMOA.EQ.2) THEN
       WRITE(*,354)
       WRITE(9,354)
       IF(YN6.EQ.'Y') WRITE(10,354)
354    FORMAT(1X,'(3) ECONOMIZER METHOD',21('.'),1X,'OUTSIDE AIR ',
    +'CONTROLLED')
```

```
      ELSE
        WRITE(*,355)
        WRITE(9,355)
        IF(YN6.EQ.'Y') WRITE(10,355)
355     FORMAT(1X,'(3) ECONOMIZER METHOD',21('.'),1X,'ENTHALPY ',
     +'CONTROLLED')
      ENDIF
      PCTOAM=PTOAM*100.
      WRITE(*,356) PCTOAM
      WRITE(9,356) PCTOAM
      IF(YN6.EQ.'Y') WRITE(10,356) PCTOAM
356   FORMAT(5X,'(3a) Minimum percentage',15('.'),F5.1,'%',/,10X,
     +'of outside air allowed')
      WRITE(*,357) FNAME,FZNAME
      WRITE(9,357) FNAME,FZNAME
      IF(YN6.EQ.'Y') WRITE(10,357) FNAME,FZNAME
357   FORMAT(1X,'(4) WEATHER DATA FILENAME',17('.'),1X,A14,/,
     +1X,'(5) ZONE UNIQUE DATA FILENAME',13('.'),1X,A14)
      IF(ISYSTM.EQ.2) THEN
        WRITE(*,358) MAXCFM
        WRITE(9,358) MAXCFM
        IF(YN6.EQ.'Y') WRITE(10,358) MAXCFM
358     FORMAT(5X,'(5a) Maximum zone primary air',9('.'),1X,A14,/,
     +10X,'volume rate & maximum induction',/,
     +10X,'air volume rate data filename')
      ENDIF
      PSFANn=100.*SFANn
      PRFANn=100.*RFANn
      PRMOTn=100.*RMOTn
      PSMOTn=100.*SMOTn
      WRITE(*,360) TPS,PSFANn
      WRITE(9,360) TPS,PSFANn
      IF(YN6.EQ.'Y') WRITE(10,360) TPS,PSFANn
360   FORMAT(1X,'(6) SUPPLY FAN DATA',/,5X,'(6a) Design total ',
     +'pressure drop',7('.'),F6.2,'(inches of water)',/,5X,'(6b)',
     +' Fan design efficiency',12('.'),F5.1,'%')
      IF(SMOTn.NE.1.0) THEN
        WRITE(*,361) PSMOTn
        WRITE(9,361) PSMOTn
        IF(YN6.EQ.'Y') WRITE(10,361) PSMOTn
361     FORMAT(5X,'(6c) Motor design efficiency',10('.'),F5.1,'%')
      ELSE
        WRITE(*,362)
        WRITE(9,362)
        IF(YN6.EQ.'Y') WRITE(10,362)
362     FORMAT(5X,'(6c) Fan motor not in airstream.')
      ENDIF
      IF((ISFAN.EQ.1).OR.(IRFAN.EQ.1)) FANTYP='VARIABLE SPEED MOTOR'
```

```
      IF((ISFAN.EQ.2).OR.(IRFAN.EQ.2)) FANTYP='INLET DAMPERS       '
      IF((ISFAN.EQ.3).OR.(IRFAN.EQ.3)) FANTYP='DISCHARGE DAMPERS   '
      IF((ISFAN.EQ.4).OR.(IRFAN.EQ.4)) FANTYP='CYCLING FAN         '
      IF(ISYSTM.EQ.2) THEN
        WRITE(*,363) FANTYP
        WRITE(9,363) FANTYP
        IF(YN6.EQ.'Y') WRITE(10,363) FANTYP
363     FORMAT(5X,'(6d) Fan air volume control method',4('.'),1X,A20)
      ENDIF
      IF(YN2.EQ.'N') THEN
        WRITE(*,364)
        WRITE(9,364)
        IF(YN6.EQ.'Y') WRITE(10,364)
364     FORMAT(1X,'(7) RETURN FAN DATA',23('.'),' RETURN FAN--NOT USED')
      ELSE
        WRITE(*,365) TPR,PRFANn
        WRITE(9,365) TPR,PRFANn
        IF(YN6.EQ.'Y') WRITE(10,365) TPR,PRFANn
365     FORMAT(1X,'(7) RETURN FAN DATA',/,5X,'(7a) Design total ',
     +'pressure drop',7('.'),F6.2,'(inches of water)',/,5X,'(7b)',
     +' Fan design efficiency',12('.'),F5.1,'%')
        IF(RMOTn.NE.1.0) THEN
          WRITE(*,366) PRMOTn
          WRITE(9,366) PRMOTn
          IF(YN6.EQ.'Y') WRITE(10,366) PRMOTn
366       FORMAT(5X,'(7c) Motor design efficiency',10('.'),F5.1,'%')
        ELSE
          WRITE(*,367)
          WRITE(9,367)
          IF(YN6.EQ.'Y') WRITE(10,367)
367       FORMAT(5X,'(7c) Fan motor not in airstream.')
        ENDIF
        IF(ISYSTM.EQ.2) THEN
          WRITE(*,368) FANTYP
          WRITE(9,368) FANTYP
          IF(YN6.EQ.'Y') WRITE(10,368) FANTYP
368       FORMAT(5X,'(7d) Fan air volume control method',4('.'),1X,A20)
        ENDIF
      ENDIF
        WRITE(*,369) KCHNGE
        WRITE(9,369) KCHNGE
        IF(YN6.EQ.'Y') WRITE(10,369) KCHNGE
369     FORMAT(1X,'(8) NUMBER OF CHANGES FOR VALUES OF THE',3('.'),
     +I2,/,5X,'DEFAULT CONSTANTS')
      WRITE(*,321)
      WRITE(9,321)
      IF(YN1.EQ.'Y'.AND.YN6.EQ.'Y') WRITE(10,321)
      IF(YN1.EQ.'Y'.AND.YN6.EQ.'N') WRITE(10,320)
```

```
320  FORMAT('1',29X,'SYSTEM DATA',/,29X,13('='),//,10X,'TEMPERATURE',
    +4X,'HUMIDITY',4X,'COOLING',18X,'PERCENT',/,10X,'LEAVING',8X,
    +'RATIO',7X,'COIL',8X,'PREHEATER',4X,'OUTSIDE',/,10X,'COOLING',
    +8X,'LEAVING',5X,'LOAD',8X,'LOAD',9X,'AIR USED',/,2X,'HOUR',4X
    +,'COIL(oF)',7X,'CCOIL',7X,'(BTU/HR)',4X,'(BTU/HR)',5X,
    +'(%/100)',/,2X,4('='),4X,11('='),2(4X,8('=')),4X,9('='),4X,
    +8('='),/)
321  FORMAT(///,29X,'SYSTEM DATA',/,28X,13('='),//,10X,'TEMPERATURE',
    +4X,'HUMIDITY',4X,'COOLING',18X,'PERCENT',/,10X,'LEAVING',8X,
    +'RATIO',7X,'COIL',8X,'PREHEATER',4X,'OUTSIDE',/,10X,'COOLING',
    +8X,'LEAVING',5X,'LOAD',8X,'LOAD',9X,'AIR USED',/,2X,'HOUR',4X
    +,'COIL(oF)',7X,'CCOIL',7X,'(BTU/HR)',4X,'(BTU/HR)',5X,
    +'(%/100)',/,2X,4('='),4X,11('='),2(4X,8('=')),4X,9('='),4X,
    +8('='),/)
     DO 9 J=1,24
       IF(CFM(1,J).EQ.0.0) THEN
         WRITE(9,313) J
         WRITE(*,313) J
         IF(YN1.EQ.'Y') WRITE(10,313) J
       ELSE
         WRITE(9,295) J,TLCC(J),WLCC(J),QCCL(J),QPH(J),PTOA(J)
         WRITE(*,295) J,TLCC(J),WLCC(J),QCCL(J),QPH(J),PTOA(J)
         IF(YN1.EQ.'Y') WRITE(10,295) J,TLCC(J),WLCC(J),QCCL(J),
    +QPH(J),PTOA(J)
       ENDIF
295    FORMAT(3X,I2,8X,F5.1,7X,F7.5,2(5X,F8.1),5X,F5.2)
313    FORMAT(3X,I2,17X,'**** PRIMARY SYSTEM OFF ****')
9    CONTINUE
     DO 32 I=1,N,3
       IZN1=I
       IZN2=I+1
       IZN3=I+2
C
       IF(I.EQ.1) THEN
         WRITE(9,340)
         WRITE(*,340)
         IF(YN1.EQ.'Y') WRITE(10,341)
       ENDIF
340    FORMAT(/////,34X,'ZONE DATA',/,33X,11('='),//)
341    FORMAT('1',34X,'ZONE DATA',/,34X,11('='),//)
C
       IF(IZN1.GT.N) GOTO 181
       IF(IZN2.GT.N) GOTO 182
       IF(IZN3.GT.N) GOTO 183
C
184    WRITE(9,323) IZN1,IZN2,IZN3
       WRITE(*,323) IZN1,IZN2,IZN3
       IF((YN1.EQ.'Y').AND.(I.EQ.1)) THEN
```

```
      WRITE(10,323) IZN1,IZN2,IZN3
     ELSEIF(YN1.EQ.'Y') THEN
      WRITE(10,336) IZN1,IZN2,IZN3
     ENDIF
323  FORMAT(4X,3(8X,'ZONE',1X,I2,8X),/,5X,3(1X,22('=')))
336  FORMAT('1',4X,3(8X,'ZONE',1X,I2,8X),/,5X,3(1X,22('=')))
     WRITE(9,324)
     WRITE(*,324)
     IF(YN1.EQ.'Y') WRITE(10,324)
324  FORMAT(5X,3(1X,'PRIMARY',1X,'INDCTN',1X,'REHEAT',1X))
     WRITE(9,325)
     WRITE(*,325)
     IF(YN1.EQ.'Y') WRITE(10,325)
325  FORMAT(1X,'HOUR',3(3X,'CFM',4X,'CFM',3X,'BTU/HR',1X),/,/)
     DO 33 J=1,24
      WRITE(9,326) J,CFMZ(IZN1,J),CFMZI(IZN1,J),QRHZ(IZN1,J),
    +CFMZ(IZN2,J),CFMZI(IZN2,J),QRHZ(IZN2,J),CFMZ(IZN3,J),CFMZI
    +(IZN3,J),QRHZ(IZN3,J)
      WRITE(*,326) J,CFMZ(IZN1,J),CFMZI(IZN1,J),QRHZ(IZN1,J),
    +CFMZ(IZN2,J),CFMZI(IZN2,J),QRHZ(IZN2,J),CFMZ(IZN3,J),CFMZI
    +(IZN3,J),QRHZ(IZN3,J)
      IF(YN1.EQ.'Y') THEN
        WRITE(10,326) J,CFMZ(IZN1,J),CFMZI(IZN1,J),QRHZ(IZN1,J),
    +CFMZ(IZN2,J),CFMZI(IZN2,J),QRHZ(IZN2,J),CFMZ(IZN3,J),CFMZI
    +(IZN3,J),QRHZ(IZN3,J)
      ENDIF
326   FORMAT(2X,I2,1X,3(1X,F7.1,1X,F6.1,1X,F7.1))
33   CONTINUE
     GOTO 181
C
183  WRITE(9,327) IZN1,IZN2
     WRITE(*,327) IZN1,IZN2
     IF((YN1.EQ.'Y').AND.(I.EQ.1)) THEN
      WRITE(10,327) IZN1,IZN2
     ELSEIF(YN1.EQ.'Y') THEN
      WRITE(10,337) IZN1,IZN2
     ENDIF
327  FORMAT(4X,2(8X,'ZONE',1X,I2,8X),/,5X,2(1X,22('=')))
337  FORMAT('1',4X,2(8X,'ZONE',1X,I2,8X),/,5X,2(1X,22('=')))
     WRITE(9,328)
     WRITE(*,328)
     IF(YN1.EQ.'Y') WRITE(10,328)
328  FORMAT(5X,2(1X,'PRIMARY',1X,'INDCTN',1X,'REHEAT',1X))
     WRITE(9,329)
     WRITE(*,329)
     IF(YN1.EQ.'Y') WRITE(10,329)
329  FORMAT(1X,'HOUR',2(3X,'CFM',4X,'CFM',3X,'BTU/HR',1X),/,/)
     DO 27 J=1,24
```

```
         WRITE(9,330) J,CFMZ(IZN1,J),CFMZI(IZN1,J),QRHZ(IZN1,J),
     +CFMZ(IZN2,J),CFMZI(IZN2,J),QRHZ(IZN2,J)
         WRITE(*,330) J,CFMZ(IZN1,J),CFMZI(IZN1,J),QRHZ(IZN1,J),
     +CFMZ(IZN2,J),CFMZI(IZN2,J),QRHZ(IZN2,J)
         IF(YN1.EQ.'Y') THEN
           WRITE(10,330) J,CFMZ(IZN1,J),CFMZI(IZN1,J),QRHZ(IZN1,J),
     +CFMZ(IZN2,J),CFMZI(IZN2,J),QRHZ(IZN2,J)
         ENDIF
 330     FORMAT(2X,I2,1X,2(1X,F7.1,1X,F6.1,1X,F7.1))
 27    CONTINUE
       GOTO 181
C
 182   WRITE(9,331) IZN1
       WRITE(*,331) IZN1
       IF((YN1.EQ.'Y').AND.(I.EQ.1)) THEN
         WRITE(10,331) IZN1
       ELSEIF(YN1.EQ.'Y') THEN
         WRITE(10,338) IZN1
       ENDIF
 331   FORMAT(12X,'ZONE',1X,I2,/,6X,22('='))
 338   FORMAT('1',12X,'ZONE',1X,I2,/,6X,22('='))
       WRITE(9,332)
       WRITE(*,332)
       IF(YN1.EQ.'Y') WRITE(10,332)
 332   FORMAT(6X,'PRIMARY',1X,'INDCTN',1X,'REHEAT')
       WRITE(9,333)
       WRITE(*,333)
       IF(YN1.EQ.'Y') WRITE(10,333)
 333   FORMAT(1X,'HOUR',3X,'CFM',4X,'CFM',3X,'BTU/HR',/,/)
       DO 35 J=1,24
         WRITE(9,334) J,CFMZ(IZN1,J),CFMZI(IZN1,J),QRHZ(IZN1,J)
         WRITE(*,334) J,CFMZ(IZN1,J),CFMZI(IZN1,J),QRHZ(IZN1,J)
         IF(YN1.EQ.'Y') THEN
           WRITE(10,334) J,CFMZ(IZN1,J),CFMZI(IZN1,J),QRHZ(IZN1,J)
         ENDIF
 334     FORMAT(2X,I2,2X,F7.1,1X,F6.1,1X,F7.1)
 35    CONTINUE
C
 181   CONTINUE
C
 32   CONTINUE
C
C=========SHOWS RUNNING TIME PER HOUR FOR CYCLING SYSTEM============
C
      IF(ISYSTM.EQ.3) THEN
       WRITE(*,371)
       WRITE(9,371)
       IF(YN1.EQ.'Y') WRITE(10,371)
```

```
371    FORMAT(/////,26X,'SYSTEM RUNNING TIME',//,6(1X,'HOUR',1X,
     +'MIN/HR'),/,6(1X,4('='),1X,6('=')),/)
       DO 42,J=1,24
42     RUNTME(J)=60.*FRHR(J)
       DO 43 K=1,4
         MM1=K
         MM2=K+4
         MM3=K+8
         MM4=K+12
         MM5=K+16
         MM6=K+20
         WRITE(*,372) MM1,RUNTME(MM1),MM2,RUNTME(MM2),MM3,
     +RUNTME(MM3),MM4,RUNTME(MM4),MM5,RUNTME(MM5),MM6,RUNTME(MM6)
         WRITE(9,372) MM1,RUNTME(MM1),MM2,RUNTME(MM2),MM3,
     +RUNTME(MM3),MM4,RUNTME(MM4),MM5,RUNTME(MM5),MM6,RUNTME(MM6)
         IF(YN1.EQ.'Y') WRITE(10,372) MM1,RUNTME(MM1),MM2,
     +RUNTME(MM2),MM3,RUNTME(MM3),MM4,RUNTME(MM4),MM5,RUNTME(MM5),
     +MM6,RUNTME(MM6)
372      FORMAT(6(2X,I2,3X,F4.1,1X))
43     CONTINUE
      ENDIF
      CLOSE(10)
C
C=========ALLOWS FOR PRINTING OF THE PERMANENT INPUT FILES==========
C
      CALL PRINPUT
C
C=========PAPER ADVANCE IF RESULTS ARE PRINTED======================
C
      IF(YN1.EQ.'Y') THEN
        OPEN(10,FILE='LPT1')
        WRITE(10,322)
322     FORMAT(2('1',/))
        CLOSE(10)
      ENDIF
C
      STOP
      END
```

```
$NOFLOATCALLS
$STORAGE:2
C
      SUBROUTINE HUMID
C
      IMPLICIT REAL (A-H,L,P-Z)
      DIMENSION HFGZ(50),PWS(24),WLCCM(24)
      COMMON/AAAAA/CFM(50,24),CFMZ(50,24),N,JX,IMOA,ICNTRL,ISYSTM,
     +MIN,MN,AD(50),ADZ(50),ACFM(50),ACFMZ(50),FRHR(24),FRHRA
      COMMON/BBBBB/DTD(50),DTDT(50),DTDZ(50),V,VD,L(50),LZ(50),TPL,
     +TO(50),TOO,UD
      COMMON/DDDDD/CPMMIX,CPMLCC,CPMR,CPA,CPV,CPL,HGLCC,HLCC,HOA,HRA
      COMMON/FFFFF/SPVA(50),UCZ,AZ(50),QLGZ(50,24),TZ(50,24),TOA(24)
     +,TWB(24),FRQLGT,TPL1,TPLA,FLUXW,QPLW(50),AMXECON
      COMMON/GGGGG/QSZ(50,24),QLZ(50,24),TSUPRZ(50),DTRH(50),QRHZ(50,24)
      COMMON/HHHHH/RH(24),PTOA(24),TMIX,SPVZ(50),WOAS,WOA,WLCC(24),
     +WZ(50),WR,WMIX,IFLAG1,TLCC(24),TR(24),IWCHK,SPVSC,PTOAM,HG,
     +TLCCF,IFLAG2,IFLAG3,IFLAG4,STOA(150),STLCC(150),TLCCA(24)
      COMMON/IIIII/SFHP,RFHP,TPS,TPR,SFANn,RFANn,SMOTn,RMOTn,DTSF,
     +DTRF,SFPLD(4),RFPLD(4),AMXTLCC
      COMMON/JJJJJ/QCCL(24),QPH(24),FRQL
C
C=========SET INITIAL RETURN AND LEAVING COIL TEMPERATURES==========
C
      IF((JX.EQ.1).AND.(IFLAG1.EQ.0)) TR(JX)=TPL
      IF((JX.GT.1).AND.(IFLAG1.EQ.0)) TR(JX)=TR(JX-1)
      IF(ICNTRL.EQ.1) TLCC(JX)=TLCCF
      IF((JX.EQ.1).AND.(IFLAG3.EQ.0).AND.(ICNTRL.NE.1)) TLCC(1)=TOO
      IF((JX.GT.1).AND.(IFLAG3.EQ.0).AND.(ICNTRL.NE.1)) TLCC(JX)=
     +TLCC(JX-1)
C
C=========COMPUTE THE OUTSIDE HUMIDITY RATIO=======================
C
      WOAS=(8.616466E-4)+(7.214287E-5)*TWB(JX)-(9.044161E-7)*(TWB(JX
     +)**2)+(5.952877E-8)*(TWB(JX)**3)-(4.841947E-10)*(TWB(JX)**4)+(
     +3.305658E-12)*(TWB(JX)**5)
      HG=1061.365+.4338772*TOA(JX)
      HGR=1061.365+.4338772*TR(JX)
      HGLCC=1061.365+.4338772*TLCC(JX)
      HGSAT=1061.365+.4338772*TWB(JX)
      HFSAT=-32.34752+1.016946*TWB(JX)-(2.111917E-4)*(TWB(JX)**2)+(7.
     +802479E-7)*(TWB(JX)**3)
      WOA=(CPA*(TWB(JX)-TOA(JX))+WOAS*(HGSAT-HFSAT))/(HG-HFSAT)
C
C=========THE CONDITION LEAVING THE COILS IS BASED ON A VARIABLE====
C=========RELATIVE HUMIDITY-COMPUTE THE COIL LEAVING HUMIDITY RATIO=
C
      WLCCS=(8.616466E-4)+(7.214287E-5)*TLCC(JX)-(9.044161E-7)*(TLCC
```

```
     +(JX)**2)+(5.952877E-8)*(TLCC(JX)**3)-(4.841947E-10)*(TLCC(JX)
     +**4)+(3.305658E-12)*(TLCC(JX)**5)
C
      TLCCA(JX)=TLCC(JX)+459.67
      C8=-10440.4
      C9=-11.2946669
      C10=-0.02700133
      C11=0.12897060E-4
      C12=-0.2478068E-8
      C13=6.5459673
      PWS(JX)=EXP(C8/TLCCA(JX)+C9+C10*TLCCA(JX)+C11*(TLCCA(JX)**2)+
     +C12*(TLCCA(JX)**3)+C13*ALOG(TLCCA(JX)))
      PSTD=14.696
      C14=PWS(JX)/PSTD
      WLCCM(JX)=WLCCS*RH(JX)*(1.0-C14)/(1.0-RH(JX)*C14)
      WLCC(JX)=WLCCM(JX)
C
C=========COMPUTE THE ZONE HUMIDITY RATIO AND SPECIFIC VOLUME=======
C
 25   DO 2 I=1,N
        SPVO=13.33
        HFGZ(I)=1093.27-.5654665*TZ(I,JX)
 10     IF((CFMZ(I,JX).EQ.0.0).OR.(FRHRA.EQ.0.0)) THEN
          WZ(I)=WLCC(JX)
        ELSE
          WZ(I)=WLCC(JX)+QLZ(I,JX)*SPVO/(CFMZ(I,JX)*HFGZ(I)*60.
     +*FRHRA)
        ENDIF
        SPVZ(I)=0.0252112*(TZ(I,JX)+459.7)*(1.0+1.6078*WZ(I))
        DIFSPV=ABS((SPVZ(I)-SPVO)/SPVO)
        IF(DIFSPV.GT.0.001) THEN
          SPVO=SPVZ(I)
          GOTO 10
        ENDIF
 2    CONTINUE
C
C=========COMPUTE THE RETURN HUMIDITY RATIO========================
C
      AMWR=0.0
      DO 3 I=1,N
 3    AMWR=AMWR+(CFMZ(I,JX)*WZ(I)/SPVZ(I))
      IF(CFM(1,JX).EQ.0.0) THEN
        WR=WLCC(JX)
      ELSE
        CONST=(TR(JX)+459.7)*((AMWR*(1.0-FRDL)*0.0252112/(CFM(1,JX))
     +)+(FRDL*WLCC(JX)/((1.0+1.6078*WLCC(JX))*(TLCC(JX)+459.7))))
        WR=CONST/(1-1.6078*CONST)
      ENDIF
```

```
C
C=========COMPUTE THE OUTSIDE AIR, RETURN AIR AND LEAVING===========
C=========COIL AIR ENTHALPIES.=====================================
C
      HOA=CPA*TOA(JX)+HG*WOA
      HRA=CPA*TR(JX)+HGR*WR
      HLCC=CPA*TLCC(JX)+HGLCC*WLCC(JX)
C
C=========COMPUTE THE LEAVING COIL AND RETURN AIR SPECIFIC HEATS.===
C
      CPMLCC=(CPA+CPV*WLCC(JX))/(1.+WLCC(JX))
      CPMR=(CPA+CPV*WR)/(1.+WR)
C
C=========CALL SUBROUTINES TO DETERMINE AIR TEMPERATURE RISE DUE====
C=========TO FANS AND THE PERCENTAGE OF OUTSIDE AIR TO BE USED.=====
C
      CALL DTFAN
      CALL PCTOAIR
C
C=========COMPUTE THE COOLING COIL ENTERING HUMIDITY RATIO & TEMP.==
C
      WMIXA=PTOA(JX)*WOA+(1.0-PTOA(JX))*WR
C
 20   C4=((1.-PTOA(JX))*(1.+1.6078*WMIXA)*TR(JX))/(((1.+1.6078*WR)*
     +(TR(JX)+459.7))+(PTOA(JX)*TOA(JX))*(1.+1.6078*WMIXA)/((TOA(JX)
     ++459.7)*(1.+1.6078*WOA))
      TMIX=459.7*C4/(1-C4)
C
      C5=(TMIX+459.7)*PTOA(JX)*WOA/((TOA(JX)+459.7)*(1.0+1.6078*WOA))
      WMIX=((1.0-PTOA(JX))*WR+C5)/(1.0-C5*1.6078)
C
      C6=ABS((WMIX-WMIXA)/WMIXA)
      C7=ABS((WLCC(JX)-WMIX)/WMIX)
C
      IF(C6.GT.0.001) THEN
        WMIXA=WMIX
        GOTO 20
      ENDIF
C
      CPMMIX=(CPA+CPV*WMIX)/(1.+WMIX)
C
C=========DETERMINE IF THE MAXIMUM HUMIDITY RATIO LEAVING===========
C=========THE COILS HAS BEEN REACHED(i.e. WET COIL)=================
C
      IF(WMIX.GE.WLCCM(JX)) THEN
        IWCHK=2
        RETURN
      ELSEIF((WMIX.LT.WLCCM(JX)).AND.(C7.GT.0.001)) THEN
```

```
        WLCC(JX)=WMIX
        IWCHK=1
        GOTO 25
      ELSEIF((WMIX.LT.WLCCM(JX)).AND.(C7.LE.0.001)) THEN
        WLCC(JX)=WMIX
        IWCHK=1
        RETURN
      ENDIF
C
      RETURN
      END


$NOFLOATCALLS
$STORAGE:2
C
      SUBROUTINE DTFAN
C
      IMPLICIT REAL (A-H,L,P-Z)
      COMMON/AAAAA/CFM(50,24),CFMZ(50,24),N,JX,IMOA,ICNTRL,ISYSTM,
     +MIN,MN,AD(50),ADZ(50),ACFM(50),ACFMZ(50),FRHR(24),FRHRA
      COMMON/BBBBB/DTD(50),DTDT(50),DTDZ(50),V,VD,L(50),LZ(50),TPL,
     +TO(50),TOO,UD
      COMMON/DDDDD/CPMMIX,CPMLCC,CPMR,CPA,CPV,CPL,HGLCC,HLCC,HOA,HRA
      COMMON/FFFFF/SPVA(50),UCZ,AZ(50),QLGZ(50,24),TZ(50,24),TOA(24)
     +,TWB(24),FRQLGT,TPL1,TPLA,FLUXW,QPLW(50),AMXECON
      COMMON/HHHHH/RH(24),PTOA(24),TMIX,SPVZ(50),WOAS,WOA,WLCC(24),
     +WZ(50),WR,WMIX,IFLAG1,TLCC(24),TR(24),IWCHK,SPVSD,PTOAM,HG,
     +TLCCF,IFLAG2,IFLAG3,IFLAG4,STOA(150),STLCC(150),TLCCA(24)
      COMMON/IIIII/SFHP,RFHP,TPS,TPR,SFANn,RFANn,SMOTn,RMOTn,DTSF,
     +DTRF,SFPLD(4),RFPLD(4),AMXTLCC
      COMMON/JJJJJ/QCCL(24),QPH(24),FRDL
C
C=========NOTE. DISTANCE FROM COIL TO SUPPLY FAN IS ASSUMED=========
C=========      TO BE NEGLIGIBLE.=================================
C
      IF(CFM(1,JX).EQ.0.0) THEN
        DTSF=0.0
        DTRF=0.0
        SPVSD=(TLCC(JX)+459.7)*(1.+1.6078*WLCC(JX))*0.0252112
        GOTO 10
      ENDIF
C
C=========COMPUTE THE DESIGN TEMPERATURE RISE ACROSS SUPPLY FAN=====
C
      DSFHP=TPS*ACFM(1)/(SFANn*6350.)
      DSMHP=DSFHP/SMOTn
      SPVSD=(TLCC(JX)+459.7)*(1.+1.6078*WLCC(JX))*0.0252112
```

```
      DDTSF=DSMHP*SPVSD*2545./(ACFM(1)*CPMLCC*60.)
C
C=========COMPUTE THE DESIGN TEMPERATURE RISE ACROSS RETURN FAN=====
C
      DRFHP=TPR*ACFM(1)*(1.0+FRDL)/(RFANn*6350.)
      DRMHP=DRFHP/RMOTn
      SPVRD=(TR(JX)+459.7)*(1.+1.6078*WR)*0.0252112
      DDTRF=DRMHP*SPVRD*2545./(ACFM(1)*(1.0+FRDL)*CPMR*60.)
C
C=========COMPUTE THE PART LOAD RATIOS===========================
C
      IF((ISYSTM.EQ.1).OR.((ISYSTM.EQ.3).AND.(ICNTRL.EQ.2))) THEN
        DTSF=DDTSF
        DTRF=DDTRF
      ELSE
        IF(ISYSTM.EQ.3) THEN
          PLD=FRHRA
        ELSE
          PLD=CFM(1,JX)/ACFM(1)
        ENDIF
        IF(PLD.EQ.0.0) THEN
          DTSF=0.0
          DTRF=0.0
          GOTO 10
        ENDIF
C
C=========COMPUTE THE PART LOAD TEMPERATURE RISES==================
C
        SPOLY=SFPLD(1)+SFPLD(2)*PLD+SFPLD(3)*(PLD**2)+SFPLD(4)*
     +(PLD**3)
        DTSF=DDTSF*SPOLY/PLD
        RPOLY=RFPLD(1)+RFPLD(2)*PLD+RFPLD(3)*(PLD**2)+RFPLD(4)*
     +(PLD**3)
        DTRF=DDTRF*RPOLY/PLD
      ENDIF
C
C=========COMPUTE THE SUPPLY AIR TEMPERATURE DOWNSTREAM OF=========
C=========SUPPLY FAN ============================================
C
 10   TOO=TLCC(JX)+DTSF
C
C=========COMPUTE THE RETURN AIR TEMPERATURE DOWNSTREAM OF=========
C=========RETURN FAN ============================================
C
      TR(JX)=TPL+DTRF
      IFLAG1=1
C
      RETURN
```

```
      END

$NOFLOATCALLS
$STORAGE:2
C
      SUBROUTINE PCTOAIR
C
      IMPLICIT REAL (A-H,L,P-Z)
      COMMON/AAAAA/CFM(50,24),CFMZ(50,24),N,JX,IMOA,ICNTRL,ISYSTM,
     +MIN,MN,AD(50),ADZ(50),ACFM(50),ACFMZ(50),FRHR(24),FRHRA
      COMMON/DDDDD/CPMMIX,CPMLCC,CPMR,CPA,CPV,CPL,HGLCC,HLCC,HOA,HRA
      COMMON/FFFFF/SPVA(50),UCZ,AZ(50),QLGZ(50,24),TZ(50,24),TOA(24)
     +,TWB(24),FRQLGT,TPL1,TPLA,FLUXW,QPLW(50),AMXECON
      COMMON/HHHHH/RH(24),PTOA(24),TMIX,SPVZ(50),WOAS,WOA,WLCC(24),
     +WZ(50),WR,WMIX,IFLAG1,TLCC(24),TR(24),IWCHK,SPVSD,PTOAM,HG,
     +TLCCF,IFLAG2,IFLAG3,IFLAG4,STOA(150),STLCC(150),TLCCA(24)
C
C=========DETERMINE WHICH ECONOMIZER CHOICE HAS BEEN MADE.==========
C
      IF(IMOA.EQ.1) GOTO 100
      IF(IMOA.EQ.2) GOTO 101
      IF(IMOA.EQ.3) GOTO 102
C
C=========PERCENTAGE OF OUTSIDE AIR FOR NO ECONOMIZER OPTION========
C
 100  PTOA(JX)=PTOAM
      RETURN
C
C=========PERCENTAGE OF OUTSIDE AIR FOR DRY BULB CONTROLLED OPTION==
C=========AMXECON IS THE MAXIMUM OUTSIDE AIR TEMPERATURE WHICH======
C=========IS ALLOWED FOR ECONOMIZER OPERATION.======================
C
 101  IF(TOA(JX).GT.AMXECON) THEN
        PTOA(JX)=PTOAM
      ELSEIF(((TOA(JX).GE.TR(JX)).AND.(TOA(JX).LE.TLCC(JX))).OR.
     +((TOA(JX).LE.TR(JX)).AND.(TOA(JX).GE.TLCC(JX)))) THEN
        PTOA(JX)=1.0
      ELSEIF(((TOA(JX).GE.TR(JX)).AND.(TR(JX).GE.TLCC(JX))).OR.
     +((TOA(JX).LE.TR(JX)).AND.(TR(JX).LE.TLCC(JX)))) THEN
        PTOA(JX)=PTOAM
      ELSE
        PTOA(JX)=(TR(JX)-TLCC(JX))/(TR(JX)-TOA(JX))
      ENDIF
      IF(PTOA(JX).LT.PTOAM) PTOA(JX)=PTOAM
      RETURN
C
C=========PERCENTAGE OF OUTSIDE AIR FOR ENTHALPY CONTROLLED OPTION==
```

```
C=========IF COIL IS DRY (i.e. IWCHK=1) THEN THE DRY BULB===========
C=========CONTROLLED ECONOMIZER IS USED.==========================
C
 102  IF(IWCHK.NE.2) GOTO 101
      IF(((HOA.GE.HRA).AND.(HOA.LE.HLCC)).OR.((HOA.LE.HRA).AND.
     +(HOA.GE.HLCC))) THEN
        PTOA(JX)=1.0
      ELSEIF(((HOA.GE.HRA).AND.(HRA.GE.HLCC)).OR.((HOA.LE.HRA).AND.
     +(HRA.LE.HLCC))) THEN
        PTOA(JX)=PTOAM
      ELSE
        PTOA(JX)=(HLCC-HRA)/(HOA-HRA)
      ENDIF
      IF(PTOA(JX).LT.PTOAM) PTOA(JX)=PTOAM
      RETURN
C
      END


$NOFLOATCALLS
$STORAGE:2
C
      SUBROUTINE TDUCT
C
      IMPLICIT REAL (A-H,L,P-Z)
      COMMON/AAAAA/CFM(50,24),CFMZ(50,24),N,JX,IMOA,ICNTRL,ISYSTM,
     +MIN,MN,AD(50),ADZ(50),ACFM(50),ACFMZ(50),FRHR(24),FRHRA
      COMMON/BBBBB/DTD(50),DTDT(50),DTDZ(50),V,VD,L(50),LZ(50),TPL,
     +TO(50),TOO,UD
      COMMON/DDDDD/CPMMIX,CPMLCC,CPMR,CPA,CPV,CPL,HGLCC,HLCC,HOA,HRA
      COMMON/EEEEE/PI,TSUPZ(50),IFLAG9
      COMMON/FFFFF/SPVA(50),UCZ,AZ(50),QLGZ(50,24),TZ(50,24),TOA(24)
     +,TWB(24),FRQLGT,TPL1,TPLA,FLUXW,QPLW(50),AMXECON
      COMMON/GGGGG/QSZ(50,24),QLZ(50,24),TSUPRZ(50),DTRH(50),QRHZ(50,24)
      COMMON/HHHHH/RH(24),PTOA(24),TMIX,SPVZ(50),WOAS,WOA,WLCC(24),
     +WZ(50),WR,WMIX,IFLAG1,TLCC(24),TR(24),IWCHK,SPVSD,PTOAM,HG,
     +TLCCF,IFLAG2,IFLAG3,IFLAG4,STOA(150),STLCC(150),TLCCA(24)
      COMMON/IIIII/SFHP,RFHP,TPS,TPR,SFANn,RFANn,SMOTn,RMOTn,DTSF,
     +DTRF,SFPLD(4),RFPLD(4),AMXTLCC
C
                           IFLAG9=0
C
C=========COMPUTE THE AIR VOLUME IN TRUNK DUCT SECTION==============
C
      DO 1 I=1,N
        IR=N+1-I
        CFMTR=0.0
        DO 2 K=1,I
```

```
          JR=N+1-K
   2      CFMTR=CFMTR+CFMZ(JR,JX)
 1      CFM(IR,JX)=CFMTR
C
C=========SET INITIAL CONDITIONS AT BEGINNING OF DUCT SYSTEM========
C
      DO 3 I=1,N
        IF (I .EQ. 1) THEN
          CFM(I,JX)=CFM(1,JX)
          LTR=0.0
          TOTR=TOO
          DTDTR=0.0
        ELSE
          CFM(I,JX)=CFM(I-1,JX)-CFMZ(I-1,JX)
          LTR=L(I-1)
          TOTR=TO(I-1)
          DTDTR=DTDT(I-1)
        ENDIF
C
C=========COMPUTE THE TEMPERATURE RISE IN THE TRUNK DUCT SECTIONS ==
C
        IF((CFM(I,JX).EQ.0.0).OR.(FRHRA.EQ.0.0).OR.((L(I)-LTR).EQ.
     +0.0)) THEN
          DTD(I)=0.0
        ELSE
          X=PI*AD(I)
          XX=(FRHRA*CFM(I,JX)*CPMLCC*30.0/(SPVSD*UD*(X**.5)*(L(I)-
     +LTR)))
          DTD(I)=(TPL-TOTR)/(XX+.5)
        ENDIF
        TO(I)=TOTR+DTD(I)
        DTDT(I)=DTDTR+DTD(I)
C
C=========COMPUTE THE TEMPERATURE RISE IN THE BRANCH DUCT SECTIONS =
C
        IF((CFMZ(I,JX).EQ.0.0).OR.(FRHRA.EQ.0.0).OR.(LZ(I).EQ.0.0)
     +) THEN
          DTDZ(I)=0.0
        ELSE
          Y=PI*ADZ(I)
          YY=(FRHRA*CFMZ(I,JX)*CPMLCC*30.0/(SPVSD*UD*(Y**.5)*LZ(I)))
          DTDZ(I)=(TPL-TO(I))/(YY+.5)
        ENDIF
C
C=========COMPUTE THE SUPPLY AIR TEMPERATURE BEING SUPPLIED=========
C=========TO EACH ZONE--BEFORE ANY REHEATING OR INDUCTION ==========
C
        TSUPZ(I)=TOO+DTDT(I)+DTDZ(I)
```

```
  3   CONTINUE
C
C=========COMPUTE THE RUNNING TIME PER HOUR FOR THE CYCLING SYSTEM.=
C
      IF((ISYSTM.EQ.3).AND.(TLCC(JX).NE.AMXTLCC)) THEN
        IF((CFMZ(1,JX).EQ.0.0).OR.(TSUPZ(1).EQ.TZ(1,JX))) THEN
          FRHR(JX)=0.0
        ELSE
          FRHR(JX)=(QSZ(1,JX)*SPVZ(1))/(CFMZ(1,JX)*CPA*(TZ(1,JX)-
     +TSUPZ(1))*60.)
        ENDIF
        IF(FRHRA.EQ.0.0) THEN
          DFRHR=0.0
        ELSE
          DFRHR=ABS((FRHRA-FRHR(JX))/FRHRA)
        ENDIF
        IF(DFRHR.GT.0.01) THEN
          FRHRA=FRHR(JX)
          IFLAG9=1
        ENDIF
      ELSEIF((ISYSTM.EQ.3).AND.(TLCC(JX).EQ.AMXTLCC)) THEN
        IF(CFMZ(1,JX).EQ.0.0) THEN
          FRHR(JX)=0.0
        ELSE
          FRHR(JX)=1.0
        ENDIF
      ENDIF
C
      RETURN
      END


$NOFLOATCALLS
$STORAGE:2
C
      SUBROUTINE QDUCTT
C
      IMPLICIT REAL (A-H,L,P-Z)
      COMMON/AAAAA/CFM(50,24),CFMZ(50,24),N,JX,IMOA,ICNTRL,ISYSTM,
     +MIN,MN,AD(50),ADZ(50),ACFM(50),ACFMZ(50),FRHR(24),FRHRA
      COMMON/BBBBB/DTD(50),DTDT(50),DTDZ(50),V,VD,L(50),LZ(50),TPL,
     +TO(50),TOO,UD
      COMMON/CCCCC/QDUCT
      COMMON/EEEEE/PI,TSUPZ(50),IFLAG9
C
C=========COMPUTE THE TOTAL DUCT SYSTEM HEAT GAIN FROM OR LOSS======
C=========TO THE PLENUM ==========================================
C
```

```
      QDA=0.0
      QDZA=0.0
C
      DO 1 I=1,N
        IF (I .EQ. 1) THEN
          TOTR=TOO
          LTR=0.0
        ELSE
          TOTR=TO(I-1)
          LTR=L(I-1)
        ENDIF
        QD=(L(I)-LTR)*(TPL-TOTR)*(AD(I)**.5)
        QDA=QDA+QD
C
        QDZ=LZ(I)*(TPL-TO(I))*(ADZ(I)**.5)
        QDZA=QDZA+QDZ
    1 CONTINUE
C
      QDUCT=2.0*(PI**.5)*UD*(QDZA+QDA)
C
      RETURN
      END


$NOFLOATCALLS
$STORAGE:2
C
      SUBROUTINE TPLENUM
C
      IMPLICIT REAL (A-H,L,P-Z)
      DIMENSION B(50)
      COMMON/AAAAA/CFM(50,24),CFMZ(50,24),N,JX,IMOA,ICNTRL,ISYSTM,
     +MIN,MN,AD(50),ADZ(50),ACFM(50),ACFMZ(50),FRHR(24),FRHRA
      COMMON/BBBBB/DTD(50),DTDT(50),DTDZ(50),V,VC,L(50),LZ(50),TPL,
     +TO(50),TOO,UD
      COMMON/CCCCC/QDUCT
      COMMON/DDDDD/CPMMIX,CPMLCC,CPMR,CPA,CPV,CPL,HGLCC,HLCC,HOA,HRA
      COMMON/FFFFF/SPVA(50),UCZ,AZ(50),QLGZ(50,24),TZ(50,24),TOA(24)
     +,TWB(24),FRQLGT,TPL1,TPLA,FLUXW,QPLW(50),AMXECON
      COMMON/HHHHH/RH(24),PTOA(24),TMIX,SPVZ(50),WOAS,WOA,WLCC(24),
     +WZ(50),WR,WMIX,IFLAG1,TLCC(24),TR(24),IWCHK,SPVSD,PTOAM,HG,
     +TLCCF,IFLAG2,IFLAG3,IFLAG4,STOA(150),STLCC(150),TLCCA(24)
      COMMON/JJJJJ/QCCL(24),QPH(24),FRDL
C
C=========COMPUTE THE PLENUM AIR TEMPERATURE, BASED ON DUCT=========
C=========LEAKAGE AIR TEMPERATURE, CEILING TRANSMISSION,============
C=========ENTERING LIGHTING ENERGY, ZONE RETURN AIR TEMPERATURE,====
C=========DUCT SYSTEM HEAT TRANSFER, AND PLENUM ENVELOPE============
```

```
C=========GAINS OR LOSSES =========================================
C
      BB=0.0
      BBBB=0.0
      QLGTZT=0.0
C
      DO 1 I=1,N
C
        B(I)=CFMZ(I,JX)*CPA*60.*FRHRA/SPVZ(I)+UCZ*AZ(I)
        BB=BB+B(I)
C
        QLGTZ=QLGZ(I,JX)*AZ(I)
        QLGTZT=QLGTZT+QLGTZ
C
        BBB=B(I)*TZ(I,JX)
        BBBB=BBBB+BBB
  1   CONTINUE
C
      DLEAK=(FRDL*60.*FRHRA*CPA*CFM(1,JX))/(SPVSD*(1.0-FRDL))
C
      IF((TOA(JX)-TPLA).LT.0.1) THEN
        FLUXW=0.0
        GOTO 10
      ENDIF
      FLUXW=QPLW(JX)/(TOA(JX)-TPLA)
      QW=FLUXW*TOA(JX)
 10   QLGTT=FRQLGT*QLGTZT
C
      IF((BB.EQ.0.0) AND (FLUXW.EQ.0.0)) THEN
        TPL1=TPLA
      ELSE
        TPL1=(BBBB+QW+QLGTT+DLEAK*TOO-QDUCT)/(BB+FLUXW+DLEAK)
      ENDIF
C
      RETURN
      END


$NOFLOATCALLS
$STORAGE:2
C
      SUBROUTINE TSZREQD
C
      IMPLICIT REAL (A-H,L,P-Z)
      DIMENSION RHCHK(50)
      COMMON/AAAAA/CFM(50,24),CFMZ(50,24),N,JX,IMOA,ICNTRL,ISYSTM,
     +MIN,MN,AD(50),ADZ(50),ACFM(50),ACFMZ(50),FRHR(24),FRHRA
      COMMON/DDDDD/CPMMIX,CPMLCC,CPMR,CPA,CPV,CPL,HGLCC,HLCC,HOA,HRA
```

```
      COMMON/EEEEE/PI,TSUPZ(50),IFLAG9
      COMMON/FFFFF/SPVA(50),UCZ,AZ(50),QLGZ(50,24),TZ(50,24),TOA(24)
     +,TWB(24),FRQLGT,TPL1,TPLA,FLUXW,QPLW(50),AMXECON
      COMMON/GGGGG/QSZ(50,24),QLZ(50,24),TSUPRZ(50),DTRH(50),QRHZ(50,24)
      COMMON/HHHHH/RH(24),PTOA(24),TMIX,SPVZ(50),WOAS,WOA,WLCC(24),
     +WZ(50),WR,WMIX,IFLAG1,TLCC(24),TR(24),IWCHK,SPVSD,PTOAM,HG,
     +TLCCF,IFLAG2,IFLAG3,IFLAG4,STOA(150),STLCC(150),TLCCA(24)
      COMMON/KKKKK/CFMZMX(50),CFMZMN(50,24),CFMZIM(50),CFMZI(50,24),
     +TSUPZI(50),SPVI(50),SPVS(50),IFLAG5,IFLAG6,IFLAG7,IFLAG8(50)
C
C=========COMPUTE THE REQUIRED SUPPLY AIR TEMPERATURE===============
C=========FOR EACH ZONE ============================================
C
      DO 1 I=1,N
        IF((CFMZ(I,JX).EQ.0.0).OR.(QSZ(I,JX).EQ.0.0).OR.
     +(FRHRA.EQ.0.0)) THEN
          TSUPRZ(I)=TSUPZ(I)
          DTRH(I)=0.0
          RHCHK(I)=500.0
        ELSE
C         TSUPRZ(I)=TZ(I,JX)-QSZ(I,JX)*SPVZ(I)/(CFMZ(I,JX)*CPA*60.0*
C    +FRHRA)
          TSUPRZ(I)=(60.*FRHRA*CFMZ(I,JX)*CPA*TZ(I,JX)-QSZ(I,JX)*
     +459.7*0.0252*12*(1.0+1.6078*WLCC(JX)))/(60.*FRHRA*CPA*CFMZ(I,
     +JX)+QSZ(I,JX)*0.0252*12*(1.0+1.6078*WLCC(JX)))
          DTRH(I)=TSUPRZ(I)-TSUPZ(I)
          RHCHK(I)=DTRH(I)
        ENDIF
C
C=========DETERMINE THE CONTROLLING ZONE WHEN THE ZONE==============
C=========CONTROLLED METHOD IS CHOSEN =============================
C
        IF(I.EQ.1) DTMIN=500.0
        IF(RHCHK(I).LE.DTMIN) THEN
          DTMIN=RHCHK(I)
          MIN=I
        ENDIF
 1    CONTINUE
C
      RETURN
      END


$NOFLOATCALLS
$STORAGE:2
C
      SUBROUTINE CFMREQD
C
```

```
      IMPLICIT REAL (A-H,L,P-Z)
      DIMENSION CHKCFM(50),DCFM(50)
      COMMON/AAAAA/CFM(50,24),CFMZ(50,24),N,JX,IMOA,ICNTRL,ISYSTM,
     +MIN,MN,AD(50),ADZ(50),ACFM(50),ACFMZ(50),FRHR(24),FRHRA
      COMMON/BBBBB/DTD(50),DTDT(50),DTDZ(50),V,VD,L(50),LZ(50),TPL,
     +TO(50),TOO,UD
      COMMON/DDDDD/CPMMIX,CPMLCC,CPMR,CPA,CPV,CPL,HGLCC,HLCC,HOA,HRA
      COMMON/EEEEE/PI,TSUPZ(50),IFLAG9
      COMMON/FFFFF/SPVA(50),UCZ,AZ(50),QLGZ(50,24),TZ(50,24),TOA(24)
     +,TWB(24),FRQLGT,TPL1,TPLA,FLUXW,QPLW(50),AMXECON
      COMMON/GGGGG/QSZ(50,24),QLZ(50,24),TSUPRZ(50),DTRH(50),QRHZ(50,24)
      COMMON/HHHHH/RH(24),PTOA(24),TMIX,SPVZ(50),WOAS,WOA,WLCC(24),
     +WZ(50),WR,WMIX,IFLAG1,TLCC(24),TR(24),IWCHK,SPVSD,PTOAM,HG,
     +TLCCF,IFLAG2,IFLAG3,IFLAG4,STOA(150),STLCC(150),TLCCA(24)
      COMMON/IIIII/SFHP,RFHP,TPS,TPR,SFANn,RFANn,SMOTn,RMOTn,DTSF,
     +DTRF,SFPLD(4),RFPLD(4),AMXTLCC
      COMMON/KKKKK/CFMZMX(50),CFMZMN(50,24),CFMZIM(50),CFMZI(50,24),
     +TSUPZI(50),SPVI(50),SPVS(50),IFLAG5,IFLAG6,IFLAG7,IFLAG8(50)
C
                      IFLAG5=0
                      IFLAG6=0
C
C=========RENAME THE CONTROLLING ZONE & SET CONTROL FLAGS===========
C
      IF((ICNTRL.EQ.2).AND.(IFLAG2.EQ.0)) THEN
        IF(IFLAG7.EQ.0) THEN
          MN=MIN
          IFLAG7=1
        ENDIF
        IFLAG5=1
        RETURN
      ENDIF
C
C=========IF THE ZONE CONTROLLED METHOD IS CHOSEN, SET THE==========
C=========CONTROLLING ZONE AIR FLOW TO ITS MAXIMUM AND COMPUTE======
C=========REQUIRED AIR FLOW FOR THE REMAINING ZONES.================
C
      IF(ICNTRL.EQ.2) THEN
        DO 4 I=1,N
          CHKCFM(I)=CFMZ(I,JX)
          IF((I.EQ.MN).AND.(QSZ(I,JX).NE.0.0).AND.(TLCC(JX).NE.
     +AMXTLCC)) THEN
            CFMZ(I,JX)=CFMZMX(I)
          ELSEIF(TZ(I,JX).NE.TSUPZ(I)) THEN
            IF(IFLAG8(I).EQ.1) GOTO 11
            CFMZ(I,JX)=QSZ(I,JX)*SPVZ(I)/((TZ(I,JX)-TSUPZ(I))*CPA*60.0)
            IF(CFMZ(I,JX).LE.CFMZMN(I,JX)) CFMZ(I,JX)=CFMZMN(I,JX)
            IF(CFMZ(I,JX).GT.CFMZMX(I)) THEN
```

```
            IF((QSZ(I,JX).LT.0.0).AND.(TSUPZ(I).GT.TZ(I,JX))) THEN
              CFMZ(I,JX)=CFMZMN(I,JX)
              IFLAG8(I)=1
            ELSE
              CFMZ(I,JX)=CFMZMX(I)
            ENDIF
          ENDIF
        ELSEIF(TZ(I,JX).EQ.TSUPZ(I)) THEN
          CFMZ(I,JX)=CFMZMN(I,JX)
        ENDIF
 11     CONTINUE
C
C=========COMPUTE CHANGE IN INDIVIDUAL ZONE AIR FLOW FROM===========
C=========PREVIOUS ITERATION.=======================================
C
        IF((CFMZ(I,JX).EQ.0.0).AND.(CHKCFM(I).EQ.0.0)) THEN
          DCFM(I)=0.0
        ELSEIF((CFMZ(I,JX).NE.0.0).AND.(CHKCFM(I).EQ.0.0)) THEN
          DCFM(I)=0.02
        ELSE
          DCFM(I)=ABS((CHKCFM(I)-CFMZ(I,JX))/CHKCFM(I))
        ENDIF
        IF(DCFM(I).GT.0.01) IFLAG6=1
 4     CONTINUE
C
C=========COMPUTE NEW TOTAL AIR FLOW.==============================
C
       IF(IFLAG6.EQ.1) THEN
         CFMY=0.0
         DO 5 I=1,N
 5       CFMY=CFMY+CFMZ(I,JX)
         CFM(1,JX)=CFMY
         IFLAG2=0
         RETURN
       ELSE
         GOTO 10
       ENDIF
      ENDIF
C
C=========COMPUTE INDIVIDUAL ZONE AIR FLOWS FOR FIXED SET POINT=====
C=========AND OUTSIDE AIR CONTROLLED CONTROL METHODS ===============
C
      DO 1 I=1,N
        CHKCFM(I)=CFMZ(I,JX)
        IF((DTRH(I).LE.0.0).AND.(CFMZ(I,JX).EQ.CFMZMX(I))) THEN
          GOTO 1
        ELSEIF(TZ(I,JX).NE.TSUPZ(I)) THEN
          IF(IFLAG8(I).EQ.1) GOTO 12
```

```
          CFMZ(I,JX)=QSZ(I,JX)*SPVZ(I)/((TZ(I,JX)-TSUPZ(I))*CPA*60.)
          IF(CFMZ(I,JX).LE.CFMZMN(I,JX)) CFMZ(I,JX)=CFMZMN(I,JX)
          IF(CFMZ(I,JX).GT.CFMZMX(I)) THEN
            IF((QSZ(I,JX).LT.0.0).AND.(TSUPZ(I).GT.TZ(I,JX))) THEN
              CFMZ(I,JX)=CFMZMN(I,JX)
              IFLAG8(I)=1
            ELSE
              CFMZ(I,JX)=CFMZMX(I)
            ENDIF
          ENDIF
        ELSEIF(TZ(I,JX).EQ.TSUPZ(I)) THEN
          CFMZ(I,JX)=CFMZMN(I,JX)
        ENDIF
 12     CONTINUE
C
C=========COMPUTE CHANGE IN INDIVIDUAL ZONE AIR FLOW FROM===========
C=========PREVIOUS ITERATION.=====================================
C
        IF(CFMZ(I,JX).EQ.0.0) THEN
          DCFM(I)=0.0
        ELSEIF((CFMZ(I,JX).NE.0.0).AND.(CHKCFM(I).EQ.0.0)) THEN
          DCFM(I)=0.02
        ELSE
          DCFM(I)=ABS((CHKCFM(I)-CFMZ(I,JX))/CHKCFM(I))
        ENDIF
        IF(DCFM(I).GT.0.01) IFLAG6=1
 1    CONTINUE
C
C=========COMPUTE NEW TOTAL AIR FLOW.==============================
C
      IF(IFLAG6.EQ.1) THEN
        CFMY=0.0
        DO 2 I=1,N
 2      CFMY=CFMY+CFMZ(I,JX)
        CFM(1,JX)=CFMY
        RETURN
      ENDIF
C
C=========COMPUTE THE REQUIRED INDUCTION AIR FLOW AND===============
C=========REHEAT TEMPERATURE DIFFERENCE, IF USED OR NEEDED =========
C
 10   DO 3 I=1,N
        IFLAG5=1
        SPVI(I)=(TPL+459.7)*(1.0+1.6078*WR)*(0.0252112)
        SPVS(I)=(TSUPZ(I)+459.7)*(1.0+1.6078*WLCC(JX))*(0.0252112)
        IF(CFMZ(I,JX).EQ.CFMZMX(I)) THEN
          CFMZI(I,JX)=0.0
          GOTO 3
```

```
      ELSEIF((CFMZ(I,JX).GT.CFMZMN(I,JX)).OR.(QSZ(I,JX).EQ.0.0)) THEN
        CFMZI(I,JX)=0.0
        DTRH(I)=0.0
        GOTO 3
      ELSEIF(TPL.GT.TZ(I,JX)) THEN
        CFMZI(I,JX)=(((QSZ(I,JX)/(60.*CPA))-(CFMZ(I,JX)*(TZ(I,JX)-
     +TSUPZ(I))/SPVS(I)))*SPVI(I))/(TZ(I,JX)-TPL)
         IF(CFMZI(I,JX).LT.CFMZIM(I)) THEN
           DTRH(I)=0.0
           IF(CFMZI(I,JX).LT.0.0) CFMZI(I,JX)=0.0
         ELSE
           CFMZI(I,JX)=CFMZIM(I)
           TSUPZI(I)=(((CFMZ(I,JX)*(TZ(I,JX)-TSUPZ(I))/SPVS(I))-
     +(QSZ(I,JX)/(CPA*60.))+(TZ(I,JX)*CFMZIM(I)/SPVI(I)))*SPVI(I))
     +/CFMZIM(I)
           DTRH(I)=TSUPZI(I)-TPL
         ENDIF
      ELSEIF(TPL.LT.TZ(I,JX)) THEN
        CFMZI(I,JX)=CFMZIM(I)
        TSUPZI(I)=(((CFMZ(I,JX)*(TZ(I,JX)-TSUPZ(I))/SPVS(I))-
     +(QSZ(I,JX)/(CPA*60.))+(TZ(I,JX)*CFMZIM(I)/SPVI(I)))*SPVI(I))
     +/CFMZIM(I)
        DTRH(I)=TSUPZI(I)-TPL
      ENDIF
      IF((DTRH(I).GT.-0.5).AND.(DTRH(I).LT.0.0)) DTRH(I)=0.0
 3    CONTINUE
C
      RETURN
      END


$NOFLOATCALLS
$STORAGE:2
C
      SUBROUTINE SETTLCC
C
      IMPLICIT REAL (A-H,L,P-Z)
      DIMENSION TOAA(24)
      COMMON/AAAAA/CFM(50,24),CFMZ(50,24),N,JX,IMDA,ICNTRL,ISYSTM,
     +MIN,MN,AD(50),ADZ(50),ACFM(50),ACFMZ(50),FRHR(24),FRHRA
      COMMON/BBBBB/DTD(50),DTDT(50),DTDZ(50),V,VD,L(50),LZ(50),TPL,
     +TO(50),TOO,UD
      COMMON/FFFFF/SPVA(50),UCZ,AZ(50),QLGZ(50,24),TZ(50,24),TOA(24)
     +,TWB(24),FRQLGT,TPL1,TPLA,FLUXW,QPLW(50),AMXECON
      COMMON/GGGGG/QSZ(50,24),QLZ(50,24),TSUPRZ(50),DTRH(50),QRHZ(50,24)
      COMMON/HHHHH/RH(24),PTOA(24),TMIX,SPVZ(50),WOAS,WOA,WLCC(24),
     +WZ(50),WR,WMIX,IFLAG1,TLCC(24),TR(24),IWCHK,SPVSD,PTOAM,HG,
     +TLCCF,IFLAG2,IFLAG3,IFLAG4,STOA(150),STLCC(150),TLCCA(24)
```

```
      COMMON/11111/SFHP,RFHP,TPS,TPR,SFANn,RFANn,SMOTn,RMOTn,DTSF,
     +DTRF,SFPLD(4),RFPLD(4),AMXTLCC
C
                       IFLAG3=1
C
C=========COMPUTE THE LEAVING COIL AIR TEMPERATURE FOR THE==========
C=========FIXED SET POINT CONTROL METHOD.==========================
C
      IF(ICNTRL.EQ.1) THEN
        TLCC(JX)=TLCCF
        IFLAG2=1
        RETURN
      ENDIF
C
C=========COMPUTE THE LEAVING COIL AIR TEMPERATURE FOR THE==========
C=========ZONE CONTROLLED CONTROL METHOD.==========================
C
      IF(ICNTRL.EQ.2) THEN
        IF(ISYSTM.EQ.2) MIN=MN
        TLCC1=TSUPRZ(MIN)-DTDT(MIN)-DTDZ(MIN)-DTSF
        IF(TLCC1.GT.AMXTLCC) TLCC1=AMXTLCC
        D1=ABS((TLCC(JX)-TLCC1)/TLCC(JX))
        IF(D1.GT.0.001) THEN
          TLCC(JX)=(TLCC(JX)+TLCC1)/2.0
          RETURN
        ELSE
          TLCC(JX)=TLCC1
          IFLAG2=1
          RETURN
        ENDIF
      ENDIF
C
C=========COMPUTE THE LEAVING COIL AIR TEMPERATURE FOR THE==========
C=========OUTSIDE AIR CONTROLLED CONTROL METHOD.===================
C
      IF(ICNTRL.EQ.3) THEN
        NSTEP1=1
 10     XYZ=ABS(TOA(JX)-STOA(NSTEP1))
C
        IF(XYZ.LT.0.5) THEN
          TLCC(JX)=STLCC(NSTEP1)
          IFLAG2=1
          RETURN
        ELSEIF(STOA(NSTEP1).EQ.200.0) THEN
C
C=========FLAGS THE USER WHEN AN OUTSIDE AIR TEMPERATURE============
C=========IS ENCOUNTERED THAT DOES NOT HAVE A CORRESPONDING=========
C=========LEAVING COIL TEMPERATURE CONTAINED IN THE USER============
```

```
C=========INPUT CONTROL SCHEDULE.==================================
C=========NOTE: THE REST OF THE SIMULATION WILL BE BYPASSED=========
C=========IF THIS OCCURS.==========================================
C
          WRITE(*,30) JX,TOA(JX)
 30       FORMAT(1X,'OUTSIDE AIR TEMPERATURE ENCOUNTERED IN HOUR'1X,I3,
     +/,1X,'(i.e.',F6.2,'(oF)) IS BEYOND THE RANGE OF YOUR CONTROL',
     +/,1X,'SCHEDULE.  EITHER YOUR CONTROL METHOD OR SCHEDULE MUST',
     +/,1X,'BE CHANGED.',/,/)
          IFLAG4=1
          RETURN
        ELSE
          NSTEP1=NSTEP1+1
          GOTO 10
        ENDIF
      ENDIF
C
      RETURN
      END


$NOFLOATCALLS
$STORAGE:2
C
      SUBROUTINE QRHEAT
C
      IMPLICIT REAL (A-H,L,P-Z)
      DIMENSION CFMRH(50,24)
      COMMON/AAAAA/CFM(50,24),CFMZ(50,24),N,JX,IMOA,ICNTRL,ISYSTM,
     +MIN,MN,AD(50),ADZ(50),ACFM(50),ACFMZ(50),FRHR(24),FRHRA
      COMMON/DDDDD/CPMMIX,CPMLCC,CPMR,CPA,CPV,CPL,HGLCC,HLCC,HOA,HRA
      COMMON/EEEEE/PI,TSUPZ(50),IFLAG9
      COMMON/GGGGG/QSZ(50,24),QLZ(50,24),TSUPPZ(50),DTRH(50),QRHZ(50,24)
      COMMON/HHHHH/RH(24),PTOA(24),TMIX,SPVZ(50),WOAS,WOA,WLCC(24),
     +WZ(50),WR,WMIX,IFLAG1,TLCC(24),TR(24),IWCHK,SPVSD,PTOAM,HG,
     +TLCCF,IFLAG2,IFLAG3,IFLAG4,STOA(150),STLCC(150),TLCCA(24)
      COMMON/KKKKK/CFMZMX(50),CFMZMN(50,24),CFMZIM(50),CFMZI(50,24),
     +TSUPZI(50),SPVI(50),SPVS(50),IFLAG5,IFLAG6,IFLAG7
C
C=========COMPUTE THE REHEAT LOAD, BASED ON REHEATING PRIMARY=======
C=========AIR SUPPLIED WITH THE TERMINAL REHEAT AND CYCLING=========
C=========SYSTEMS AND SECONDARY AIR WITH THE VAV SYSTEM ============
C=========NOTE: THE PROGRAM WILL "REHEAT" THE VAV PRIMARY AIR=======
C=========      IF A NEGATIVE REHEAT IS REQUIRED.(i.e. AIR==========
C=========      BEING SUPPLIED NOT COOL ENOUGH TO SATISFY LOADS.)===
C
      DO 1 I=1,N
        IF((ISYSTM.EQ.2).AND.(DTRH(I).GE.0.0)) THEN
```

```
          CFMRH(I,JX)=CFMZ(I,JX)
        ELSE
          CFMRH(I,JX)=CFMZ(I,JX)
        ENDIF
        IF(ABS(DTRH(I)).LT.0.3) DTRH(I)=0.0
 1      QRHZ(I,JX)=CFMRH(I,JX)*60.*FRHRA*CPMLCC*DTRH(I)/(0.0252112*
     +(TSUPZ(I)+459.7)*(1.0+1.6078*WLCC(JX)))
C
      RETURN
      END


$NOFLOATCALLS
$STORAGE:2
C
      SUBROUTINE QCCOIL
C
      IMPLICIT REAL (A-H,L,P-Z)
      COMMON/AAAAA/CFM(50,24),CFMZ(50,24),N,JX,IMOA,ICNTRL,ISYSTM,
     +MIN,MN,AD(50),ADZ(50),ACFM(50),ACFMZ(50),FRHR(24),FRHRA
      COMMON/BBBBB/DTD(50),DTDT(50),DTDZ(50),V,VD,L(50),LZ(50),TPL,
     +TO(50),TOO,UD
      COMMON/DDDDD/CPMMIX,CPMLCC,CPMR,CPA,CPV,CPL,HGLCC,HLCC,HOA,HRA
      COMMON/FFFFF/SPVA(50),UCZ,AZ(50),QLGZ(50,24),TZ(50,24),TOA(24)
     +,TWB(24),FRQLGT,TPL1,TPLA,FLUXW,QPLW(50),AMXECON
      COMMON/HHHHH/RH(24),PTOA(24),TMIX,SPVZ(50),WOAS,WOA,WLCC(24),
     +WZ(50),WR,WMIX,IFLAG1,TLCC(24),TR(24),IWCHK,SPVSD,PTOAM,HG,
     +TLCCF,IFLAG2,IFLAG3,IFLAG4,STOA(150),STLCC(150),TLCCA(24)
      COMMON/IIIII/SFHP,RFHP,TPS,TPR,SFANn,RFANn,SMOTn,RMOTn,DTSF,
     +DTRF,SFPLD(4),RFPLD(4),AMXTLCC
      COMMON/JJJJJ/QCCL(24),QPH(24),FRDL
C
C=========COMPUTE THE MASS FLOW RATE===============================
C
      AMDOT=CFM(I,JX)*60.*FRHRA/((TMIX+459.7)*(1.+1.6078*
     +WMIX)*0.0252112*(1.0-FRDL))
C
C=========COMPUTE THE MIXED(ENTERING COIL) AIR ENTHALPY.============
C
      HMIX=PTOA(JX)*HOA+(1.0-PTOA(JX))*HRA
C
      HFLCC=-31.85414+.9987608*TLCC(JX)
      DTCC=TMIX-TLCC(JX)
      IF(ABS(DTCC).LE.0.25) DTCC=0.0
      DTPH=-DTCC
C
C=========DETERMINE IF COOLING OR PREHEATING IS REQUIRED ===========
C
```

```
      IF(HMIX.LT.HLCC) THEN
        QCCL(JX)=0.0
        GOTO 10
      ENDIF
C
C=========DETERMINE IF COIL IS WET OR DRY.=========================
C
      IF(IWCHK.EQ.1) THEN
        DWCC=0.0
      ELSE
        DWCC=WMIX-WLCC(JX)
      ENDIF
C
C=========CALCULATE COOLING COIL LOAD ============================
C
      QCCL(JX)=AMDOT*(HMIX-HLCC-DWCC*HFLCC)
      IF(QCCL(JX).LT.500.0) QCCL(JX)=0.0
      QPH(JX)=0.0
      GOTO 20
C
C=========CALCULATE PREHEATER LOAD.==============================
C
 10   QPH(JX)=AMDOT*CPMMIX*(DTPH)
C
 20   RETURN
      END


$NOFLOATCALLS
$STORAGE 2
C
      SUBROUTINE PRINPUT
C
      IMPLICIT REAL (A-H,L,P-Z)
      CHARACTER YNPRINT
      CHARACTER*9 MINIMUM
      CHARACTER*14 DESIGN(50)
      COMMON/AAAAA/CFM(50,24),CFMZ(50,24),N,JY,IMOA,ICNTRL,ISYSTM,
     +MIN,MN,AD(50),ADZ(50),ACFM(50),ACFMZ(50),FRHP(24),FRHPA
      COMMON/BBBBB/DTD(50),DTDT(50),DTDZ(50),V,VD,L(50),LZ(50),TPL,
     +TO(50),TOO,UD
      COMMON/FFFFF/SPVA(50),UCZ,AZ(50),QLGZ(50,24),TZ(50,24),TOA(24)
     +,TWB(24),FRQLGT,TPL1,TPLA,FLUXW,QPLW(50),AMXECON
      COMMON/GGGGG/QSZ(50,24),QLZ(50,24),TSUPRZ(50),DTRH(50),QRHZ(50,24)
      COMMON/HHHHH/PH(24),PTOA(24),TMIX,SPVZ(50),WOAS,WOA,WLCC(24),
     +WZ(50),WR,WMIX,IFLAG1,TLCC(24),TR(24),IWCHK,SPVSD,PTOAM,HS,
     +TLCCF,IFLAG2,IFLAG3,IFLAG4,STOA(150),STLCC(150),TLCCA(24
      COMMON/KKKKK/CFMZMX(50),CFMZMN(50,24),CFMZIM(50),CFMZI(50,24),
```

```
     +TSUPZ1(50),SPV1(50),SPVS(50),IFLAG5,IFLAG6,IFLAG7,IFLAG8(50)
C
C=========DETERMINE IF PRINTED COPIES OF INPUT FILES ARE DESIRED.===
C
 10   WRITE(*,254)
 254  FORMAT(//,1X,'DO YOU WANT A HARD COPY OF THE PERMANENT INPUT',
     +/,1X,'FILES (i.e. WEATHER, LOADS, SCHEDULES, etc.)(Y/N)?  ',\)
      READ(*,'(A1)') YNPRINT
      IF(YNPRINT.EQ.'N') RETURN
      IF((YNPRINT.NE.'Y').AND.(YNPRINT.NE.'N')) THEN
        WRITE(*,*) ' YOU MUST ANSWER EITHER "Y" OR "N".'
        GOTO 10
      ENDIF
C
C=========NAME THE ZONES.===========================================
C
      WRITE(*,255) N
 255  FORMAT(//,1X,'ENTER THE DESIGNATOR (i.e. NORTH,WEST,OFFICE 1,'
     +,'etc.) FOR EACH ZONE.',/,1X,'YOU WILL NEED DESIGNATORS FOR ',
     +I2,' ZONES ',/,1X,'THEY MUST BE LESS THAN 15 CHARACTERS EACH '
     +,//)
      DO 3 I=1,N
        WRITE(*,256) I
 256    FORMAT(' ',1X,'DESIGNATOR FOR ZONE ',I2,'  ',\)
        READ(*,257) DESIGN(I)
 257    FORMAT(A14)
 3    CONTINUE
C
C=========PRINT THE WEATHER INPUT DATA FILE ========================
C
      OPEN(11,FILE='LPT1')
      WRITE(11,250)
 250  FORMAT('1',////,33X,'WEATHER FILE DATA',/,32X,19('='),//,
     +59X,'MAX  REL ',/,14X,'OUTSIDE',9X,'OUTSIDE',9X,'PLENUM',
     +7X,'HUMIDITY',/,14X,'DRY BULB',8X,'WET BULB',8X,'ENVELOPE',
     +5X,'EXITING',/,7X,'HOUR',3X,'TEMPERATURE',5X,'TEMPERATURE',5X,
     +'LOAD',9X,'COILS',/,18X,'(oF)',12X,'(oF)',8X,'(BTU/HR)',8X,
     +'(%)',/,7X,4('='),3X,11('='),5X,11('='),5X,8('='),5X,9('='),//)
      DO 1 I=1,24
      WRITE(11,251) I,TOA(I),TWB(I),QPLW(I),100.*RH(I)
 251  FORMAT(8X,I2,6X,F6.2,10X,F6.2,8X,F8.1,6X,F6.2)
 1    CONTINUE
C
C=========PRINT THE LEAVING COIL VERSUS OUTSIDE AIR SCHEDULE========
C=========FOR THE OUTSIDE AIR CONTROLLED CONTROL METHOD ONLY.=======
C
      IF(ICNTRL.EQ.3) THEN
        WRITE(11,252)
```

```
 252    FORMAT('1',22X,'OUTSIDE DRY BULB TEMPERATURE',/,23X,
     +'VS. COIL LEAVING TEMPERATURE',/,22X,28('='),//
     +,5X,'OUTSIDE',9X,'LEAVING',/,5X,'DRY BULB',8X,'COIL',/,
     +5X,'TEMPERATURE',5X,'TEMPERATURE',/,9X,'(oF)',12X,'(oF)',
     +/,2(5X,11('=')),//)
C
        ICHECK=0
C
        DO 2 I=1,150
          IF(STOA(I).EQ.999.) ICHECK=1
          IF(ICHECK.EQ.1) GOTO 2
          WRITE(11,253) STOA(I),STLCC(I)
 253      FORMAT(8X,F6.1,10X,F6.1)
 2      CONTINUE
      ENDIF
C
      IF(ISYSTM.EQ.2) THEN
        MINIMUM='MINIMUM '
      ELSE
        MINIMUM='        '
      ENDIF
C
C=========PRINT THE ZONE UNIQUE INPUT DATA FILE ===================
C
      DO 4 I=1,N
        WRITE(11,258) DESIGN(I),AZ(I),L(I),LZ(I),UCZ
 258    FORMAT('1',///,5X,'INPUT DATA FOR ZONE NAMED ',A14,' ',//,8X
     +,'ZONE AREA',21X,F12.5,' SQ FT ',/,8X,'TRUNK DUCT LENGTH TO ',
     +'BRANCH',3X,F12.5,' FT ',/,8X,'BRANCH DUCT LENGTH',12X,F12.5,
     +' FT ',/,8X,'CEILING "U" VALUE',13X,F12.5,' BTU/HR-SQ FT -oF')
        WRITE(11,259) MINIMUM
 259    FORMAT(///,30X,A8,15X,'TOTAL',5X,'LIGHTING',/,10X,'SENSIBLE'
     +,2X,'LATENT',4X,'AIR FLOW',2X,'SET POINT',4X,'LIGHTING',2X,
     +'ENERGY TO',/,4X,'HOUR',2X,'LOAD',6X,'LOAD',6X,'RATE',6X,
     +'TEMPERATURE',2X,'ENERGY*',3X,'PLENUM*',/,10X,'(BTU/HR)',2X,
     +'(BTU/HR)',2X,'(CFM)',8X,'(oF)',5X,'(BTU/HR)',2X,'(BTU/HR)',/
     +4X,4('='),3(2X,8('=')),2X,11('='),2X,8('='),2X,9('='),//)
C
        DO 5 K=1,24
          IF(ISYSTM.EQ.2) THEN
            WRITE(11,260) K,QSZ(I,K),QLZ(I,K),CFMZMN(I,K),TZ(I,K)
     +QLGZ(I,K)*AZ(I),QLGZ(I,K)*AZ(I)*FRQLGT
          ELSE
            WRITE(11,260) K,QSZ(I,K),QLZ(I,K),CFMZ(I,K),TZ(I,K),
     +QLGZ(I,K)*AZ(I),QLGZ(I,K)*AZ(I)*FRQLGT
          ENDIF
 260      FORMAT(5X,I2,2X,F9.1,2X,F9.1,2X,F9.1,5X,F5.1,5X,F9.1,2X,
     +F9.1)
```

```
 5      CONTINUE
C
        WRITE(11,262)
 262    FORMAT(//,3X,'*NOTE: THE ENERGY ENTERING THE ZONE IS ',
     +'INCLUDED IN THE SENSIBLE LOAD.')
C
C=========PRINT THE MAXIMUM PRIMARY AND SECONDARY AIR FLOW==========
C=========RATES FOR THE VAV SYSTEM ONLY.===========================
C
        IF(ISYSTM.EQ.2) THEN
          WRITE(11,261) CFMZMX(I),CFMZIM(I)
 261      FORMAT(////,20X,'MAXIMUM PRIMARY',5X,'MAXIMUM INDUCTION',
     +/,20X,'AIR  FLOW  RATE',5X,'AIR   FLOW   RATE',/,25X,'(CFM)',
     +16X,'(CFM)',/,15X,2(5X,15('=')),2('='),//,22X,F9.2,12X,F9.2)
        ENDIF
 4    CONTINUE
C
      CLOSE(11)
C
      RETURN
      END
```

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VITA

Michael Kent Reardon [redacted] the son of John Michael Reardon, Jr. and Margaret Cecilia Reardon. After completing his work at North Attleborough High School, North Attleborough, Massachusetts, in 1976, he entered The University of Massachusetts in Amherst, Massachusetts. He received the degree of Bachelor of Science in Mechanical Engineering from The University of Massachusetts and was commissioned a second lieutenant in the United States Air Force in May, 1980. During the following years he served in the United States Air Force at Minot Air Force Base, Minot, North Dakota and Misawa Air Base, Misawa City, Japan. In September, 1985, he entered The Graduate School of The University of Texas at Austin.

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